JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE

State of Pennsylvania,

AND

AMERICAN REPERTORY.

OCTOBER, 1843.

Franklin Institute.

COMMITTEE ON SCIENCE AND THE ARTS.

Report on the best modes of Paving Highways.

The Committee on Science and the Arts, constituted by the Franklin Institute, of the State of Pennsylvania, for the promotion of the Mechanic Arts, to whom was referred the following portion of a joint resolution of the Select and Common Councils of the City of Philadelphia, passed January 5th, 1843, to wit: "Resolved, That the Franklin Institute, be requested to communicate to Councils, any information they may think proper, in relation to the best modes of paving highways," REPORT thereon as follows:

(Continued from Page 168.)

2. *Of Pebble Pavements.*—Pavements of rounded water worn pebbles, or small boulder stone, have been, and still are, so extensively used in almost every country, that they must be familiar to all who have ever examined the subject in hand, and will, consequently, require but a brief description.

The *pebble pavements* employed in the city and districts of Philadelphia, are generally constructed as follows:

The natural soil is first excavated to a depth of about 20 or 24 inches below the top of the curbstone, so as to receive a bed of gravel at least 12 inches deep; this gravel is not compacted otherwise than by the occasional passage of the carts hauling it, and the pebbles to the place; the pebbles are set by hand upon the gravel bed, and well rammed three times over, gravel is then spread, and kept upon the surface for some time after the street is opened for travel, in order that all the interstices between the pebbles may become firmly filled.

The pebbles employed, are generally elliptical in their vertical sections, and usually run from five to ten inches in depth, the largest and

rudest shaped pebbles, being selected to pave the sides of the street while the rest are reserved, and used, for the middle of the carriage way.

The curbstones used within the city proper, are divided into two classes of the following dimensions:

1st. class, 24 inches deep; 5 ins. thick; and 4 ft. minimum length.
2nd. " 15 " 4 " " 3 " "

The first class, when set, costs about 45 cents, and the second class 30 cents per foot lineal; these curbstones are usually of gneiss rock, and are not dressed as well as they ought to be; indeed, many of them are scarcely dressed at all, but are set in the street, nearly as they come from the quarry.

The curbstones used in the districts adjacent to the city, are of somewhat smaller dimensions, and cost nearly the same per lineal foot, when set.

Curbstones are usually set to show from six to eight inches vertically, clear of the brick gutters, though, in some extreme cases, where a great flow of water takes place, they have been made to show a foot without augmenting their depth; but wherever they project so much, they are disturbed by the frost in such manner, as to require resetting annually—in fact, to possess a proper degree of stability, a curbstone ought not to show above the gutter, more than one-third of its depth.

The streets paved with pebbles have a rounded surface formed in the transverse section, by means of a flat curve, the crown of which rises generally from six to nine inches above the gutter levels.

The gutters formed upon each side of the carriage way, to drain off the surface water to the sewers, are generally laid transversely with bricks on edge, and are, consequently, about nine inches in width.

The footways are commonly paved with bricks laid flat, "*herring-bone fashion*," and ascend, from the curbstones to the buildings, at the rate of a half inch rise, to one foot base.

The cost of the pebble pavements in Philadelphia, has been determined by long experience, and may be divided into two classes.

Firstly, where a new street is paved, inclusive of the brick gutters, and of all materials and workmanship, the aggregate expense is from ninety cents, to one dollar, per square yard of surface, measuring the whole horizontal space between the curbstones.

Secondly, where an old street is repaved, in which case, small quantities of new materials are required, and the expense varies from 40 to 50 cents per superficial yard of the whole surface between the curbs.

We learn from the last report of the city commissioners—for which, and other important information, we are indebted to Adam Traquair, their president—that during the year 1842, there were made, under the orders of the city commissioners, 5,590 square yards of *new paving*, at an aggregate expense of $ 5,269.83, *or*, 94 *cents per superficial yard.*

From the same source we have ascertained, that during the same

year, 1842, there were executed within the city, 13,012 square yards of *repaving*, at a total outlay of $ 6,305.47, *or* 48 *cents per superficial yard.*

In the district of Moyamensing, *the new pebble pavements* have cost from 90 to 95 cents per square yard; and in some of the other districts, the same quality of work has been done for private individuals, *at* 90 *cents per superficial yard.*

At present it is probable, that 90 cents per square yard for *new paving*, and 45 cents per square yard for *repaving*, are, respectively, fair prices for the pebble pavements, as they now are executed; and even if they were done in a superior manner, one dollar for the former, and a half dollar for the latter, would still be a sufficient remuneration.

The curbstones and footways, under the laws now in force, are paid for by the private individuals whose lots they front, and are not chargeable upon the public treasury.

Such is a brief account of the cost and execution of the pebble pavements of Philadelphia; and we conceive that this kind of paving may be improved in quality, without the necessity of incurring much additional expense.

Thus we think that the gravel foundation ought not to be less than 16 inches deep, though this increased depth of 4 inches, will, at the average price of gravel, add about 5 cents per square yard to the cost of the pavement.

The gravel, instead of being loosely thrown in, ought to be well compacted, by rolling it in *three layers* with a heavy roller, and the top should be finished off with a depth of loose gravel merely sufficient to receive the pebbles.

The pebbles themselves ought to be of good form, and should be sized, so as not to be less than 6, nor more than 8 inches in depth, and all rude, unshapely masses ought to be rejected entirely.

It is not easy to prescribe exact dimensions for stones so irregular as pebbles from their nature are; but in selecting them, none should be received, which, when properly set, would be of greater diameter horizontally, than vertically.

Probably the best shape for these paving stones, would be (to speak in mathematical language) *that of a prolate spheroid, generated by an ellipse, of which the major axis is double the length of the minor one*, such a stone when set in a pavement, would present flat curved ends, and if 8 inches deep, would be 4 inches thick at the middle.

This description of stone ought to be kept in view, and approximated to, in purchasing and selecting suitable pebbles for a pavement; though, as a matter of course, it is not absolutely necessary to be very precise in affairs of this nature, and the inspection will probably be sufficiently rigid, if, from a mass of pebbles of general good shape, we reject all that have greater breadth in their proper position, than they have depth; or, in other words, if we reject all that are flatter than spheres.

The pebbles being carefully selected, and set by hand in the 16 inch foundation of gravel, should be well rammed *thrice over*, and,

finally, the whole surface should be covered over 3 inches deep with gravel, which should be allowed to remain under the travel for one month; and whenever from frequent sweeping, or other causes, the gravel works out from between the pebbles, and allows them to project boldly up, the street should then immediately be regravelled, as above, or it will soon break up in consequence of the stone having lost their lateral support.

With regard to *repaving* an old street, we will here remark, that an injudicious practice prevails in this city upon such occasions, of loosening up, and hauling off, a part of the gravel foundation of the old pavement which had become firmly consolidated by use, and supplying its place, at some expense, with loose material, by no means equal, as a foundation, to that which is usually dug up and carried away; this practice, certainly, ought to be terminated, as being not only useless, but positively injurious.

We find that the same practice prevailing in London, as well as here, induced a person named Hobson, in 1827, to take out a patent in England, with the view of obviating its evils, and as some of the remarks in Hobson's specification appear to be judicious, if not novel, we will quote a portion of it, as follows:

"Instead of picking up the ground loose, (as is the practice in the present mode of repaving) ram the ground, on which the paving is to be placed, well down until it is as solid as possible, to a form corresponding with the form the surface of the paving is to take when finished."

"The stones employed should be sorted, so as to be nearly of an equal depth."

A pebble pavement constructed as we have above indicated, *would cost, for new paving, about a dollar, and for repaving, about a half-dollar, per superficial yard;* measuring, as usual, the whole horizontal space between the curbstones, and including the brick gutters in the above prices.

The value of a firm foundation for a pebble pavement, is well exemplified in a statement made to us, by Messrs. Price and Fox, the surveyors of the district of Spring Garden, which was to the following effect:

"That in forming the pebble pavement upon the Ridge Road, where the old turnpike was, the surface of that turnpike road was as little disturbed as possible, and where it was least disturbed, and the least gravel was used, that part has stood admirably, better, indeed, than any other pavement in the district; and no part of the old turnpike road being much below the bottom of the pebble pavement, it has all stood well."

The comparative superiority, in point of durability, of the pebble pavement laid upon the rudely paved surface of the old Ridge turnpike, as described before us, by the surveyors of Spring Garden, is certainly a strong corroborative argument in favor of stable foundations for all pavements, and confirms the propriety of the preference given by us, in a previous part of this report, to a sub-pavement of pebbles, as a foundation for a pavement of dressed stone.

3. *Of stone tramways combined with pebble pavements.*—Tramways are lines, or ribands, of stone, or metal, to receive the wheels of carriages traveling along them; they are spaced from middle to middle, at the usual distance apart of the wheels of common road vehicles, and like the railways of the same name, (which they resemble, omitting the upright flanch) they are designed to carry, indiscriminately, the carriages in use upon the usual highways of the country.

These *tramways*, or trackways, as they are also sometimes called, are usually formed of two parallel lines, or rails, of long stone, from 18 to 24 inches broad, and about a foot thick, upon which the wheels of passing carriages move, whilst the horse-path, or space between them, as well as the rest of the roadway, is usually paved with pebbles.

The leading example of this mode of paving highways, is to be found in the streets of Milan, where the tramways are of stone, a yard in breadth, and where the beauty and excellence of the carriage ways have long formed a theme of admiration for travelers in upper Italy.

Tramways of cast iron plates, 2 inches thick, and 8 inches wide, laid upon stone supports, flush with the surface of the road, have been used with complete success, in the streets of Glasgow, to reduce the traction upon a hill which rises at the rate of 1 in 20; and on this grade they enabled horses to draw up 4 tons with apparent ease: but it must be admitted, however, that notwithstanding their utility, cast iron tramways are objectionable on account of their expense.

John MacNeill, a distinguished English civil engineer, several years ago, stated, in an article on Tramways, that, ... "Trackways of granite have been lately laid on the turnpike road between Coventry and Nuneaton, and are found to answer exceedingly well. In this case, as the horses work two abreast, they are obliged to travel on the stone tracks as they work in the lines of the wheels; in the others already mentioned, the carts, or wagons, are drawn only by one horse in the shafts, by which means he travels on the pavements between the lines, and not on the tracks themselves. This, however, produces no inconvenience whatever, and no obstruction to the horses, from slipping, or any other cause."

Sir Henry Parnell remarks, in relation to this subject, that "the plan of paving which contributes most to diminish the labor of moving heavy weights on roads, is that of forming as hard and smooth a surface as can be formed, with stone for the wheels of carriages to roll upon. This is effected by making use of large blocks of granite, or other hard stone. Roads of this kind, when the blocks are about 16 inches wide, and are laid in parallel lines, are commonly called stone tramways, or trackways."

"On a well constructed road, or trackway, of this kind, it has been proved by experiment, that a London draught horse can draw on the level, *ten tons*."

Stone tramways were used by Sir Thomas Telford, upon the great Holyhead road, with the most decided advantage, to diminish traction upon hills, where the configuration of the country compelled him to adopt inclinations of 1 in 20.

In such cases nearly the same advantage in reducing the draught of carriages, results from the use of tramways, as would be obtained by cutting down the hills one half, and making the surface of the road of broken stone alone.

The commercial road from the West India Docks to Whitechapel, London, which was constructed under the direction of James Walker, C. E., in 1829, is a well known example of the advantageous character of stone tramways.

It is made "with large blocks of granite, five or six feet in length, sixteen inches wide, and twelve inches deep, laid for the wheels to run upon, as on a tramroad of iron, except that there is no flanch. The space between the granite blocks is paved."

The foundations of stone tramways have usually been made either of a rough pavement, dressed off with broken stone of small size, as in Telford's mode of forming highways, or else the tramway blocks have been laid down upon a bed of broken stone alone.

Either of these plans will, doubtless, answer the purpose, but we have reason to believe, that a well rolled gravel foundation, *will generally be sufficiently solid*, if the blocks of the tramways are made two feet in width, so as to distribute the pressure over an extended surface.

Nevertheless, in streets where a very heavy travel is anticipated, it may, perhaps, be found advisable, in preparing the foundations for the blocks composing the tramway, to form under the centre of each line, a pebble pavement, say three feet wide, then to cover this with about two inches depth of gravel, well, and firmly rolled, and, finally, upon this well compacted surface of gravel, to lay down the tramway.

The stone blocks, to form a good tramway, ought to be dressed with their top surfaces parallel to their beds, their ends wrought square, so as to fit close, and their sides scabbled off, so as to be vertical, and nearly parallel when set: *the blocks to be about two feet wide, one foot thick, and from four to six feet in length.*

The upper surfaces of the tramway should be flush with the general outline of the carriage way, and the pavement of pebbles between the lines of stone blocks, ought not to have any more curvature than is due to the general transverse profile of the street.

Stone tramways, such as have been above referred to, will, undoubtedly, form a very superior highway; they strongly recommend themselves for use in the American cities, on account of their comparative cheapness, and, excepting for the leading thoroughfares, where a smooth and uniform surface over the whole width of the carriage way, is demanded by a crowded travel, stone tramways would certainly afford all the necessary facilities for transportation, whilst their economy, the ease of traction over them, the smoothness of the motion, and reduction of the noise of passing vehicles, would be found very advantageous.

We may now conclude this branch of the subject, by inviting attention to the great advantages possessed by tramways, in their superior applicability to all inclinations, however high may be the gradient

of the street; since, whilst affording upon the intermediate pebbles, a secure foothold for the horses which draw the passing vehicles, the carriage wheels rolling upon the smooth parallel lines of stone blocks, experience less resistance than they meet with upon any other form of stone pavement, and this advantageous property renders tramways superior for some situations, even to pavements of dressed stone, since the latter become too slippery under foot, when applied to streets having a strong grade; and hence, would be inapplicable to the inclinations descending to the Delaware front of Philadelphia, whilst, for such slopes, stone tramways would be particularly suitable.

Section V.

Pavements Suitable to Philadelphia.

In forming an opinion of the kinds of pavement which seem to be the best suited to the circumstances of Philadelphia, the relative cost of the several plans, has, in every case, been closely considered, and that consideration has led us to recommend the adoption of the following system of paving, not, perhaps, as being the best possible, but as the best attainable by a moderate outlay; and, we have, moreover, in our estimates of cost, *sought rather to err in excess, than in deficiency.*

As has been done before by others, it will be sufficient for us to divide the streets into three classes, dependent upon the extent and character of the travel carried by each.

Streets of the first class, or the leading thoroughfares of the city, possessing, by our hypothesis, a very heavy and crowded travel, will eventually require a smooth, and durable surface for the whole breadth of the carriage way, *and, consequently, ought ultimately to be uniformly paved with blocks of dressed stone, disposed in the diagonal manner, upon a sub-pavement of pebbles;* this species of pavement, if executed in the substantial manner recommended by us, *will cost about three dollars per superficial yard.*

This price is certainly a large one, when compared with the cost of the same extent of other kinds of pavements, and hence, we presume, that it will be found necessary to employ pavements of dressed stone in Philadelphia, with a very sparing hand, in consequence of the great expense attending them, though, for streets filled with a crowded travel, there would seem to be no other pavement equally suitable.

The cost of the rude specimen of stone block pavement now laid in this city in Chesnut street, between Fourth and Fifth, was about $ 2.50 per square yard of surface, exclusive of the gutter stone, which were a separate charge; and the president of the city commissioners informs us, that the stone blocks delivered upon the sidewalks for the pavement in Chesnut, between Fifth and Sixth streets, cost $ 2 per square yard of the surface they will lay; and that the total expense of that pavement, will not, probably, exceed $ 2.50 per square yard, or the same as that of the pavement east of Fifth street.

In forming pavements of dressed stone for carriage ways, it is necessary to confine their application to those streets which have gentle

inclinations, since, if applied upon hills, they would prove too slippery for advantageous use by horses.

It is probable that the inclination in Chesnut street, descending eastward from Fourth street, which has a grade of $2\frac{9}{10}$ feet rise, to 100 feet base, or 1 in 34, is as steep as any upon which the use of dressed stone pavements would be advisable; and it would not seem to be expedient to employ them upon any of the hills descending to the Delaware front of the city, since, excepting Spruce street, where the descent is gentle, they have gradients varying from *seven* to *nine* feet rise, for an hundred feet base, or inclinations from 1 in 14, up to the strong grade of 1 in 11.

For streets of the second class, or those of medium travel, which include the majority of the public highways of Philadelphia, *we recommend the employment of stone tramways, combined with pebble pavements,* such as have been briefly described in the fourth section of this report.

A pavement of this nature, though of quite an imperfect character in point of materials and workmanship, was laid in the year 1837, in Arch street, between Twelfth and Thirteenth, which is still in tolerable order, though it has received but trivial repairs since being put in use, notwithstanding that the stone blocks composing the tramways, were too soft, of unequal texture, and had scarcely received any dressing to cause them to fit each other, or to bring their surfaces into line.

We regard this experiment, in view of all the circumstances attending it, as being signally successful, and this fact, when superadded to the favorable considerations we have previously mentioned, and to the successful use of stone tramways elsewhere, appears to us to offer the strongest inducements for extending the use of pavements of this nature here.

The stone tramway blocks employed in Arch street, cost $37\frac{1}{2}$ cents per lineal foot of each line, or if we suppose two tramways, or four lines of blocks, to be laid in a street of 26 feet carriage way, they would, at that rate, clear of the intervening pebble pavement, cost about *fifty cents* per square yard of the whole surface between the curb-stones, or, in other words, they would exceed the cost of an ordinary pebble pavement, as follows, if we include with the tramways, the intervening pavements of pebbles with which they are combined, to wit:

Taking for example 9 ft. lineal of pebble pavement with a 26 ft. carriage way, we should have 26 sq. yds. at 50c.,	$ 13.00
Now, taking 9 ft. lineal of pebble pavement, and stone tramways combined, we should have 36 lin. ft. of blocks at $37\frac{1}{2}$c.,	$ 13.50
26 sq. yds. of pebble pavement less $2 \times 4 \times 9 = 8$ sq. yds. occupied by the tramway blocks, if 2 ft. in width, or $26 - 8 = 18$ sq. yds. peb. pav. at 50c., - -	9.00
Or 26 sq. yds., at $86\frac{1}{2}$c., = - - - - -	$ 22.50
Difference,	$ 9.50

Or $\frac{\$\ 9.50}{26} = 36\frac{1}{2}$c. per square yard.

Hence, from the above calculation, it appears that if a 26 feet carriage way were laid with two stone tramways, and pebble pavements combined, then, at the prices assumed above, such a pavement would cost 86½ cents per square yard of the whole surface, or 36½ cts. more than the general average cost of *repaving* a street in a proper manner with pebbles alone.

Since the tramways in Arch street, however, were formed of stone of smaller dimensions, and inferior quality, to those which we recommend for use, the material of the latter would cost more.

Nevertheless, since, in repaving streets, we do not contemplate the removal of the existing consolidated gravel foundations—a source hitherto of considerable unnecessary expense—since, contracting for large amounts of stone tramway blocks at once, would reduce the price per foot lineal, and, since the tramway stones themselves would occupy about one-third of the surface of the carriage way, in a street of the common width of 50 feet from house to house; we entertain the opinion, that to repave a street, already paved with pebbles, in a proper manner, and insert suitable stone tramways, two in number, or four lines of stone blocks, *would not cost more than one dollar per square yard of the whole surface between the curbstones, if the usual brick gutters are used.*

Such a price for a good repaving, and introducing stone tramways into our streets, would seem to be within the compass of moderate means; and hence, we are the more strongly induced to request the particular attention of the city authorities to pavements of this species, and earnestly to recommend their gradual adoption for the great majority of the highways of Philadelphia, or streets of the second class, as we have designated them.

For streets of the third class, being those which carry the least travel, and include the minor streets, with all the lanes, and alleys, we recommend in general, a continuance of the present mode of paving with water worn pebbles, employing, however, the improvements which have been suggested; and employing, too, in some of the various alleys which carry much travel, a species of tramway formed of smaller blocks than in the main streets; since a precaution of this kind appears to be necessary in some of them, as the cart-wheels traveling always on the same track, are found to destroy the pebble pavements very rapidly.

Such pebble pavements when composed of stone of proper shape and quality, averaging about 6 inches in depth, and set in a sufficient bed of gravel, appear to form the cheapest, and most suitable surfaces for streets, lanes, and alleys, where the travel is not great, and if they be executed as we have proposed, *the cost of new paving streets in a proper manner, with good pebbles, will not exceed one dollar per square yard, whilst the average cost of repaving, will, probably, fall short of a half dollar for the same extent of surface*, since, as we have before intimated, we would not, in repaving a street with pebbles, attempt to pick up, and remove the existing well consolidated gravel foundations, where yet of sufficient depth, but would simply

add as much new gravel as might be found necessary to restore the street pavement, when finished, to its proper height and profile.

This course would be both less expensive, and less laborious, whilst it would make a better pavement than the method usually pursued at this time in repaving our streets.

In each and all of the above plans, the gutters and curbstones may be formed as is at present customary, though it would be a great improvement, if stone gutters, and cut granite curbing joggled together, were more generally introduced into our leading streets.

In addition to what we have said in reference to *pebble pavements*, we would recommend that the pebbles employed, *should be, as far as practicable, sorted into sizes*, so that the depths of the pavements formed with them, may be as uniform as possible; and so that no necessity shall exist of intermixing large and small stones in the same pavement at random, which tends to produce inequality of surface, and is, doubtless, a source of instability.

In a pavement of dressed stone, the diagonal system might be brought into play, by a "*herring-bone*" disposition of the stone blocks, as in the brick footways, if it were not for the necessity which would thence arise, of hewing all the stones like bricks, to exact dimensions; a mode of proceeding, which would, to some extent, enhance the cost of the pavement, without apparently producing a commensurate benefit.

Section VI.

Plans and Specifications of the Pavements recommended.

In the event of the paving and repaving of Philadelphia being annually let out *by contract*, at such prices as may be fixed by the public competition of responsible men—the propriety of which we shall discuss in the next section of this report—it will be proper in all cases to accompany the contract by a detailed specification of the work to be done, which will form, in fact, a part of the article of agreement between the parties, and which ought to be illustrated, when necessary, by drawings upon a large scale publicly exhibited, and explained to all applicants at the time of giving out the contracts.

This plan of proceeding is that which, for many years, has been customary in letting out the work to be done on the public improvements of the country, and has been shown by ample experience to be both explicit and satisfactory.

We, therefore, propose in this section, briefly to indicate some of the leading points which ought to be embodied in drawing up specifications to govern the construction of the three kinds of pavement which have been recommended by us for adoption; leaving the details, however, to be filled in by those who may have charge of the work, on the part of the city.

A Specification for a Pavement of Dressed Stone, should provide;

1. That the stone themselves be of uniform quality for any one street, and of hard, tough, and durable rock, well rammed when set.

2. That the stone blocks be rectangular parallelopipeds, nearly

cubical in shape; that all the sides be wrought at right angles to each other, or full to the square, and in such manner, that, when set, no joint shall show an opening of more than one quarter of an inch, whilst, in general, they shall be but three-sixteenths.

3. That the depths of all the blocks shall be, uniformly, *exactly eight inches;* that the breadths may vary from 7 to 9 inches, and the lengths from 8 to 10 inches, provided, however, in case of any variation from the standard breadth of 8 inches, sufficient stone of each breadth shall be furnished to form a complete diagonal course with its triangular closers, and that the separate breadths employed, shall be all determined by iron gauges, applied by those who dress them, and marked with paint upon the showing surface of each stone, as fast as they are dressed off, so as to facilitate the laying down of the pavement.

4. That in point of materials and workmanship, the prepared stone when delivered, shall be fully equal to duplicate specimens dressed to the requisite fineness of joint, and submitted by every contractor along with his proposal.

5. That the transverse outline of the finished pavement shall be formed by causing the stone blocks to rise at once from the gutters one and a half inches, the projecting angle thus formed being either *rounded, or chamfered off*, as soon as the pavement is set; that the surface then shall form a flat curve, having an average ascent of one-fourth of an inch to the foot, from the sides to the middle of the streets, so that in a carriage way 26 feet wide, inclusive of gutters, the crown of a pavement of the proper transverse profile, would have an elevation of 4½ inches above the gutter level.

6. That the foundation shall consist of a pebble pavement, formed upon a well rolled gravel bed, of 12 inches average depth; that this sub-pavement shall extend from curb to curb, be, upon its surface, parallel to the profile fixed for the street, and be dressed off to receive the stone blocks with two inches depth of gravel, well compacted under heavy rollers, and accurately brought up parallel to the proper profile of the finished pavement.

7. That the stone blocks shall be disposed diagonally in the pavement, in courses forming angles of 45° with the axis of the street, and running forward towards the right hand; that these courses shall be terminated next the gutter stone, by triangular closers accurately dressed to fit.

8. That the gutters, and curbstones, shall be formed by long blocks of stone in the usual manner, the former being furnished, and laid, by the contractor for the pavement of dressed stone.

9. That the pavement, when finished, shall be covered over with gravel three inches deep, which shall remain on for one month after the street is opened to the public travel, in order to insure the complete filling of all the joints, and save the new pavement from concussion, until it has had time to consolidate.

10. That throughout its whole progress, all the work connected with the pavement, shall be subject to the inspection, and approval, of some officer of the city; and that the finished pavement shall not

be received from the contractor, until that officer shall certify that it has been executed in strict conformity to the specification, and contract, and to his entire satisfaction.

11. That the finished pavement shall be measured by an officer of the city; and that the contractor shall be paid the stipulated price for each *superficial yard* of the whole horizontal surface between the curbstones, inclusive of the intersections of the streets, contained within the lines of the curb produced, where they are paved by the same party.

A Specification for a Pavement of Pebbles, should provide;

1. That the stone shall be of good spheroidal shape; that they shall be river pebbles, and that they shall have an average depth of 6 inches when set.

2. That the average depth of the gravel foundation shall be 16 inches, or 13 inches deep next the gutters, and 19 inches at the crown, the base line being level from side to side.

3. That the transverse profile of the finished pavement, shall be a flat curve, having, on both sides, an average rise from the gutters to the middle, of about half an inch to the foot, so as to bring the crown of a carriage way 26 feet wide, up to an elevation of 6 inches above the gutter level.

4. That the main body of the gravel foundation shall be formed in at least two layers, well consolidated separately by rolling, and dressed off with only the quantity of loose gravel which may be actually necessary to set the pebbles properly.

5. That in setting the pebbles they shall be placed in absolute contact with each other, and that they shall be thoroughly rammed thrice over.

6. That the best shaped pebbles, shall be selected, and set to form the middle of the carriage way, while the ruder ones should be employed in paving the sides of the streets, next to the gutters.

7. That the gutters are to be formed of bricks set on edge, in the manner now usual in the city.

8, 9, and 10. Same as the 9th, 10th, and 11th points of the specification for pavements of dressed stone.

A Specification for Stone Tramways, combined with Pebble Pavements, should provide;

1. That the transverse profile of the street, the quality of the pebbles used, and the general mode of forming the pavement, should be the same as is provided for in the specifications for pebble pavements.

2. That the second layer of the gravel foundation should be brought up by rolling, precisely parallel to the intended outline of the street, and to the proper height for receiving the tramway blocks, beneath which, in particular, it should be thoroughly consolidated. The tramway blocks should then be set upon this well rolled surface, and the remainder of the pavement should be finished off flush with their surfaces, with water worn pebbles, in the usual manner.

3. That the tramway blocks should be composed of a hard, tough, and durable rock, dressed with the top and bottom beds parallel, having their ends squared off, so as to set a joint of three-sixteenths of an inch, whilst their sides should be roughly scabbled, so as to be nearly square with the beds. The dimensions of these blocks to be 2 feet wide, 1 foot thick, and from 4 to 6 feet in length, each.

4. That the four lines of stone blocks forming two tramways in a street, should be spaced equally at 5 feet apart from middle to middle, and should be set with their top surfaces flush with the prescribed outline of the street.

5, 6, and 7. Same as the 9th, 10th, and 11th points of the specification for pavements of dressed stone.

Such, in brief, are the principal points which ought to be embodied in framing specifications for the three species of pavements referred to; but there are a number of minor particulars, which, with the above, should be set out with the minute particularity usual in drawing the specifications of works of engineering, of which, in point of fact, the formation of highways is but a branch.

In the event of putting under contract the pavements of Philadelphia, proposals from responsible men should be invited through the press, for, at least, one month previously; and plans, and sections, of the several pavements, drawn upon a large scale by the city surveyor, should be prepared, and publicly exhibited. Whilst, at the same time, printed copies of the specifications, designed to control the execution of the work, should be furnished to all applicants, and explained, if necessary, by the proper officer, so that they may be clearly understood by those who propose to act under them.

With these precautions in explaining, and illustrating, beforehand, the work to be done, combined with a judicious selection of the men to do it, there will be no difficulty in finding good contractors to construct the pavements here, in a manner much superior to that at present practiced, whilst their expense, at the same time, would, undoubtedly, be diminished.

Section VII.

Superintendence and Mode of Executing the Work.

Experience upon the public works of the country has completely shown, that by far the most expensive mode in which States, or Corporations, can execute works, requiring manual labor, is to employ hands to do them by the day.

On the other hand, experience upon the same works, has also demonstrated, on a large scale, that the cheapest mode of doing work is by contract.

An objection is commonly made to contracts, upon the ground that in consequence of its being the direct interest of the contractor to slight his work, it is difficult to get it done in a sufficiently good manner.

This objection is, however, only partially valid, since the country is full of examples of excellent work done by contract. And, in fact, to procure good work from contractors, if the specifications are ex-

plicit, and the superintending officer competent to the duties of his station, but two things are necessary, to wit:

1. *That the prices of the work should be fair.*
2. *That the supervision should be stern.*

To secure the first, it will be necessary to open the work to public competition from responsible men, and to let the work at its value only to those, who are in every sense, competent to execute it.

To secure the second, it is merely requisite that the superintending officer should be honest, competent, and firm.

Though it may be true that some of the worst work in the country has been done by contract, it is equally true that some of the very best quality has also been executed in the same manner, so that no sound argument against the contract system, can be based upon the fact, that bad work has been done under it, since, that such has occasionally been the case, is almost wholly owing, either to a culpable laxity of supervision, or to indirect influence having been brought to bear upon the officer in charge of the work.

Several of the members of this committee, from their professional service upon the public works, have it in their power to state cases which fell under their own observation, where work done by the day for corporations, even under apparently good supervision, has cost far more than similar work executed for the same corporation, or in the same section of country, *by individual contract.*

This course, however, does not seem to us necessary, and might not be agreeable to persons connected with the works referred to; we shall, therefore, omit the citation of particular examples, and, backed by the experience of the country in analogous affairs, we will confine ourselves to expressing the decided opinion, *that all the paving and repaving of Philadelphia, ought to be annually let out by contract, to the lowest competent and responsible bidder, in an open competition, by proposals previously invited by ample public notice.*

To let out the formation of the public highways by contract, carries with it the necessity of placing the execution of the work under a rigid, and intelligent superintendence; and as the construction, and repair of highways is but a branch of the profession of the civil engineer, it seems to us that the most appropriate superintendent for the public highways, would be *the city surveyor*, who, from the nature of his office, should necessarily be acquainted with the elements of engineering, and, therefore, be much more competent to direct the progress of affairs of this nature, than the worthy citizen to whom they are now confided, who, being selected from the people without any particular regard to their knowledge of these subjects, cannot, in general, be expected to possess the requisite information.

In recommending, then, upon the score of economy, that the work upon the highways of Philadelphia, should be done by contract, *we also recommend that those contracts should be rigidly executed under the orders of the city surveyor, and his assistants.*

Section VIII.

Concluding Observations.

We are here induced to remark, that the great cost of pavements of dressed stone, on the one hand, and the comparative cheapness of stone tramways, upon the other, induce us to request the particular attention of the authorities of this city, to pavements of the latter description, as being, probably, the most suitable for the largest portion of the public highways.

Stone tramways possessing such advantages, in point of reducing the draught of the horses employed upon them, and being particularly applicable to hills, such as those descending to the Delaware front of the city, we would suggest the propriety of laying down tramways at an early period, in some, if not all, of the east and west streets, from Front street to the river.

In connexion with the subject in hand, we would recommend the gradual introduction, throughout the leading streets of the city, *of stone, instead of brick gutters*, the latter requiring frequent repairs, and exposing an immense number of joints to allow the filtration of water to injure the foundations of the pavement, as well as to admit of the injurious action of frost.

Gutter stone ought to be hewn from a hard, and durable rock, in lengths of from 4 to 6 feet; they should be about 12 inches wide, by 6 or 8 inches deep, or thick, and should be so dressed, that, when set, the joints shall be close, and the surface regular.

The curbstones commonly employed here, appear to have sufficient dimensions as prescribed by ordinance of councils, except, perhaps, in thickness, to which, a small addition would be desirable.

In setting curbstones, it would be a great improvement, if their joints were more closely dressed, and if an iron dowel were inserted vertically in each joint, and run with sulphur and sand, to prevent one stone from being pushed outwards, independently of another.

It is moreover to be hoped, that since the curbstones are at the expense of those private individuals whose lots they front, our citizens will more generally employ curbstones of well dressed granite, tongued and grooved together, like those fine specimens recently placed, by our enterprising townsman, Dr. Swaim, in front of his property, at the corner of Seventh and Chesnut streets, which, besides their promised durability, are certainly an ornament to the pavement.

The brick footways, also, admit of being essentially improved, by paying more attention to their foundations; thus, if, instead of employing a little loose sand for that purpose, *six inches* in depth, of good gravel, well rammed, in, at least, two successive layers, were used to receive the bricks, a decided improvement in the evenness, and stability of the sidewalks would be the result; or if, still better, the bricks were laid with good strong mortar, upon a bed of concrete from *four to six inches thick*, resting on a well rammed bed of gravel, dressed off to the proper slope; in that case our "*herring-bone*" brick

pavements* would leave nothing to be desired in point of durability, and smoothness of surface, especially if concealed gutters should come into use, instead of the open ones now employed.

As an evidence of the great durability which may fairly be expected to result from the employment of brick footways *upon solid foundations*, we refer to the well known promenade along the fore-bay, in front of the wheel-house, at Fairmount; this is paved flatwise, with the usual quality of bricks, laid directly, with a little gravel, upon the solid foundation furnished by the masonry of the head arches; and, though this pavement has been exposed to a very considerable foot travel ever since it was placed there, in the year 1822, or, *twenty-one years ago*, it has never required any repairs whatever, and is, at this moment, in excellent condition.

Since a considerable part of the expense and trouble of laying pavements of dressed stone in the diagonal manner, arises from the necessity of cutting, and fitting, triangular closers next to the gutters, it is worthy of consideration, on the part of those who have charge of the highways, whether this may not be wholly avoided, and the general pavement cheapened, by employing next to the gutters on both sides, a band of pebble paving, about two feet wide, which would economically obviate the difficulty referred to; and yet in a 26 feet carriage way, (if we allow two feet for both gutters,) a width of 20 feet of dressed stone pavement would still remain in the middle, to carry the travel of the street.

Although, for apparently sufficient reasons, we have reluctantly declined recommending a foundation of concrete, for pavements of the first class, nevertheless, if there be any single square of leading thoroughfare within the city, where all the iron, gas and water, pipes are laid, the private attachments to them all made, and the sewers completed, so that no necessity of disturbing the street is likely to occur for many years, *then, in such case, it may be advisable to lay a dressed stone pavement upon a uniform foundation of good concrete, at least one foot in thickness*, since there can be no doubt, whatever, that a pavement laid upon such a foundation, if well underdrained, would be as durable as the materials composing it, whilst few, if any, repairs would ever be required, until, in future time, complete renewal should become necessary.

The positive tone in which we anticipate great durability for a suitable pavement laid upon a well underdrained bed of good concrete, is amply justified by the experience upon the Highgate Archway road, at London, which, under the skilful management of Telford, was, by the judicious employment of concrete foundations, in a place far more unfavorable than any which exist here, converted from one of the worst, into one of the best, and most durable, roads within the limits of the British Empire.

* *Hexagonal bricks* have the most suitable figure for the purposes of paving flatwise since they may be so laid that none of the sides will be parallel to the line of travel, and thus secure the advantages of the "herring-bone" disposition; whilst, at the same time, from their form in plan, they resist tilting, and are but little liable to the breakage which may be witnessed in all old pavements, where bricks of the usual figure are employed.

Prior to concluding this report, it has occurred to us, that it would be proper to speak more specifically upon the subject of the drainage of Philadelphia; it appears from an approximate soil map, prepared at our request, by the assistant city surveyor, with the aid of an officer of the gas works, well acquainted with the various soils underlying our pavements, that a considerable portion of Philadelphia is built upon a sandy loam of such porosity that it drains with facility to lower levels, any water which may be thrown upon it, and preserves naturally a comparatively dry surface.

Another considerable portion of the city stands upon made ground, scarcely more retentive of water than the sandy loam above referred to.

Of course, then, in the districts distinguished upon the soil map by this porosity, *underdrains* to prepare the ground for the reception of pavements, will scarcely be necessary; but they may be confined with advantage—at least for the present—to the clay district, where the subsoil is retentive of water, and, therefore, needs underdrainage before it can form a suitable foundation for a pavement of any kind.

The soil map which we submit, is merely approximate in its character, and being solely designed to carry *a general idea* of the character of the soils immediately underlying the pavements, it will require verification, before it can be safely made the basis of a system of drainage.

Inasmuch as the whole city reposes upon a substratum of open gravel, at a greater, or less, depth beneath the surface, and as this porous stratum is pierced, in almost every instance, by the old public wells, now abandoned, and arched over; it is worthy of consideration whether these wells cannot be made to subserve, to some extent, the purpose of underdraining the highways, since this is a mode of drainage often successfully resorted to in the cellars of buildings here; and it has also been found very satisfactory in draining ground, upon a large scale, for agricultural purposes, many years ago, in England, as may be ascertained by reference to Johnson's able treatise upon *Drainage.*

Finally, having now discussed most of the subjects to which we had proposed to direct our attention, we may conclude by expressing the hope that some of the suggestions thrown out in the preceding report, may be found useful, and available, by the councils of Philadelphia, in improving the highways of their beautiful city.

By order of the Committee,

WILLIAM HAMILTON, Actuary.

Philadelphia, June 26th, 1843.

Civil Engineering.

Experiments on Water-Wheels, having a vertical axis, called Turbines. By Arthur Morin, Captain of Artillery, Professor of Machinery in the School of Artillery, &c. &c. *Published at Metz, and Paris,* 1838.

(Translated from the French,* by Ellwood Morris, Civil Engineer.)

I.

Of the different attempts made to improve Water-Wheels with vertical axes.

Amongst the attempts made, for some years past, to improve hydraulic motors, the one most remarkable for its success, is that of M. Fourneyron, Civil Engineer, who, with that perseverance and firmness which leads to the end, has succeeded in giving to those wheels with vertical axes, which we call *turbines*, such forms and proportions as make them valuable motors in many departments of industry.

Wheels with vertical axes, have, for a long time, been used in the Pyrenees; and the mills of Toulouse, described by Bélidor, offer a remarkable example of their present application to the grinding of corn. But these wheels, where the water enters, and leaves, by the exterior circumference, after having acted on it merely by its concussion,† do not realize, in the most favorable circumstances, more than $\frac{35}{100}$ of the power expended by the motor. This is confirmed in the experiments made in 1821, by Messrs. Tardy and Piobert, officers of Artillery; many of which will be given further on. Other wheels of the same species, established at Metz, about three centuries ago, and some of which still exist, are far from producing as much effect as those of Toulouse, and from the observations made in 1825, by M. Poncelet, on their product in grinding corn, they do not realize more than $\frac{1}{15}$th of the power expended.

M. Navier, in his notes on Bélidor's Hydraulic Architecture, has given the theory of these wheels, as well as that of one kind of wheel with curved buckets, receiving the water without shock, and letting it escape without velocity, after descending from a certain height upon the wheel following the surface of the buckets; and he has also examined the case where the water entered nearer, or farther, from the axis, than it left it. This last theory, which applied to the numerous *reaction wheels* then known, or proposed, is equally applicable to the turbine of M. Fourneyron, whilst equating to zero the full length the water traveled upon the wheel.

* Throughout *the text* of this translation, I have converted the French, into English measures; but in *the tables*, as they, in part, exhibit *ratios* which would not be altered, whilst the rest of the results tabulated, would have been much encumbered by fractions, it seemed more advisable *to retain* the French measures in these tabular statements. The *metre* is 39.371 *English inches*. The *kilogramme* 2.20485 *English pounds avoirdupois*. To *approximate* the details of any of the experiments, it will be found very convenient to call the *metre* 3 3-10 feet, and the *kilogramme* 2 1-5 pounds, neither of which values will be much in error, whilst their use very much abridges the labor of reduction to English measures.

† These are what we commonly call tub-mills.—Trans.

M. Poncelet in his lectures to the school of practice of the Artillery and Engineers, at Metz, had given, in 1826, a description and theory of a wheel with curved buckets, and a vertical axis, analogous to his wheel of the same species, of which the axis is horizontal, and which received the water without shock through many points of its exterior circumference, and allowed it to escape without velocity through the interior.

In 1833, M. Burdin, Engineer of Mines, proposed, and put to work, another species of wheels with a vertical axis, described in the Annals of Mines, third series, vol. iii, and has given to them the name of *Turbines*, which has since been applied to all wheels with vertical axes, capable of moving when immersed in the water, of the lower level.

But it was reserved for the perseverance of M. Fourneyron, who, since 1823, has occupied himself with this question, to attain the degree of perfection to which these wheels have been brought. In a memoir inserted in the Bulletin of the (French) Society for the Encouragement of National Industry, in the year 1833, this engineer has given a description of the wheel which he constructed, and for which he has secured a patent.

Respect for the rights so justly acquired by long labor, will prevent us from giving all the information which we have been able to collect, and of which we owe a part to the engineer, as to the forms and proportions of the wheels which we have submitted to experiment, and, consequently, we cannot compare the results of experiment with those of the theoretical formulas, in which these proportions enter as elements of calculation. But the point of most importance to the arts, is to know what duty we can require of this motor in various circumstances, and the results which we shall give on this particular, will, doubtless, appear sufficiently complete to warrant a positive conclusion respecting them.

II.

Experiments on the Wheels of the Mills of Toulouse.

Before reporting the results of experiments which I have lately made upon the *turbines* of M. Fourneyron, it will not be uninteresting to make known some of those, which, in 1821, had been observed by Messrs. Tardy and Piobert, on the different species of wheels of the mills of Toulouse; and from these we shall select only such as refer to the wheels which performed the best. We know* that the water is conveyed upon these wheels by a kind of pyramidal adjutage, called *the spigot*, and that after having acted by impulse upon the concave buckets of the wheel, it escapes below, and at the sides.† It was important to calculate with care, the expenditure of water made by this kind of orifice under given heads; or, in other words, to obtain its coefficient of expenditure.

These able officers determined this coefficient by observing with

* Bélidor's Hydraulic Architecture, edition by M. Navier.

† These are a species of tub-wheels.—Trans.

care the time required to empty the basins forming the reservoir above the works, and they have found 0.900 for the mean value in this case. That determined, they were enabled to calculate the expenditure of water in *the spigot* for each height of level, as well as the quantity of *absolute work, or power*, developed by the motor.

As for the *useful effect*, it was measured by the aid of an apparatus similar to the *Brake, or Friction Dynamometer* which M. de Prony proposed and employed about the same time, but which was then unknown to them.

The theoretical formula of the *useful effect* of these wheels given by M. Navier, and by M. Poncelet is,

$$Pv = \frac{1000Q}{g}(V \sin. a - v \sin. c)\ v \sin. c.$$

in which we call, (in French measures)

P = The power transmitted by the water to the circumference described by the point of impact of the mean filament upon the wheel.

Q = The volume of water expended in *one second.*

v = The velocity of the circumference of the point of impact of the water.

V = The velocity of the efficient water.

a = The angle formed by the velocity V with the bucket at the point of impact of the water.

c = The angle formed by the velocity v with the bucket at the same point.

g = 9.8088 metres. ($32\frac{1}{6}$ English feet.)

It follows from this formula that the maximum of effect must correspond to the relation,

$$v = \frac{V}{2 \sin. c.}$$

In the wheels of the mills of Toulouse, we have ordinarily, $a = 90°$, $c = 70°$, or sin. $a = 1$, sin. $c = 0.94$. For that of the New Mill,* on which the experiments were made which we are about to report, the point of impact of the mean filament was at a distance of $1\frac{74}{100}$ feet, from the axis of the wheel.

From these elements, it has been easy to form the following table, which contains the results of these experiments.

* It must be borne in mind that this is a *tub-wheel*, actuated like all such, *by impact only*.—Trans.

EXPERIMENTS on one of the Wheels of the New Mill at Toulouse.

No. of the exp.	*Weight* of water expended in one second. 1000Q	Tot'l fall.	Absolute *work* of the motor in one second.	*Velocity* of impact of the water on the wheel. V	*Velocity* of the point of impact of the water on wheel. *v*	Ratio of the velocities $\frac{v}{V}$	*Useful effect* by theory.	*Useful effect* measured by the Friction Dynamometer, or *available work.*	Ratio of the *work available* To the effect by theory.	Ratio of the *work available* To the *absol'te work* of the motor.
	Kilog.	Mtrs.	Kilog.	Metres.	Metres.		Kilog.	Kilog.		
1	341.1	4.39	1351	9.08	6.33	0.70	647	214	0.300	0.153
2	338.3	4.32	1318	9.00	6.76	0.75	581	211	0.370	0.162
3	302.8	4.26	1290	8.94	6.09	0.68	567	402	0.700	0.312
4	301.4	4.23	1275	8.91	5.76	0.65	581	408	0.700	0.320
5	299.0	4.17	1248	8.84	5.66	0.65	539	421	0.770	0.330
6	295.0	4.07	1201	8.73	5.76	0.62	539	352	0.650	0.293
7	294.0	4.04	1187	8.69	4.76	0.54	566	479	0.840	0.403
8	291.0	3.96	1151	8.60	4.99	0.58	543	451	0.830	0.393
								Mean,	0.750	0.342

[In the above table the absolute work, or power, consumed by the motor, is calculated by multiplying together the second and third columns, or is, in fact, *the weight of water descending one metre in one second,* (and, excepting the first and second experiments, which have been rejected on account of some irregularity) the other columns sufficiently explain themselves.—Trans.]

III.

Deductions from the results contained in the preceding table.

An examination of this table shows that for the values of the velocity *v* of the point of impact, or introduction, of the water on the wheel comprised between 54 and 68 *per cent.* of V, that of the effluent water, the ratio of the useful effect measured by the brake, to the useful effect by theory, is at an average equal to 75 per cent., and that, consequently, this useful effect will be represented within an eighth by the formula.

$$Pv = \frac{750Q}{g}(V \sin. a - v \sin. c)\, v \sin. c.$$

As for the ratio of the *available work,* measured by the brake, to the *absolute work, or power,* expended by the motor between the same limits, it has for a mean value,

0.342.*

which shows that these wheels return nearly as much (of the power expended) as those of good construction of which the planes of the buckets, and the axis, are horizontal, and which receive the water at the lower part (or, what we call, *undershot wheels.*—Tr.)

The relation,

$$v = \frac{V}{2 \sin. c}$$

which corresponds to the maximum of effect, gives, in the actual case, where $c = 0.94$

$$v = 0.55\, V,$$

* About the same ratio of effect to power, as was determined, for *undershot wheels,* by Smeaton, and others.—Tr.

and experiment shows that the maximum of effect agrees with the values,

$$v = 0.54\ V, \text{ and } v = 0.58\ V,$$

which agrees with the results of theory.

Thus, the experiments of Messrs. Tardy and Piobert, enable us to determine *the useful effect* of a wheel having the buckets hollow, or scooped, and the axis vertical, on which the water acts by impulse within the ordinary limits of velocity, and show that the best of these wheels *do not return more than from* 35 *to* 40 *per cent. of the power expended.*

IV.

Experiments on the Turbines of M. Fourneyron.

General description of the Turbines.—Without entering into the details of the construction, it seems to us indispensible to preface the results of the experiments by a summary description of the machines to which this memoir applies; and we will select for example, *the turbine* established in the furnaces of Fraisans, referring for a more full description, to the memoirs which the inventor has presented to the (French) Society for the Encouragement of National Industry, and which are inserted in the Bulletin of that Society, for the year 1834. The two essential parts of *the turbines* of M. Fourneyron, are *the wheel*, or ring, with curved buckets, and *the sluice.*

The wheel, *a*, *a*, (fig. 1, 2, and 3,) is formed by an upper ring of strong sheet-iron, and by a ring below, cast in a single piece, with a concave base, which we call *the cap*, *c*, *c*; these two rings concentric with the axis of rotation, are placed horizontally, and joined together by the curved buckets, *d*, *d*, placed vertically, and also made of strong sheet-iron. The *cap* is fixed on the axis of rotation, to which it is firmly bound, and which it carries along in its rotary movement.

The *sluices* consist of a fixed bottom piece, or plate, *e*, *e*, connected with a hollow cast-iron pipe, which incloses the *main shaft* of the wheel, and is sustained, in the upper part, by wood work, or by supports of masonry. On this plate, *e*, *e*, rise vertically the curved guides, *f*, *f*, designed, as we shall show presently, to give to the water the proper direction for issuing from the orifices of emission.

A hollow cylindrical casting, *g*, *g*, of which the position is parallel to the axis of rotation, is interposed between the wheel and the directing curves, or guides, and forms the *sluice-gate* properly so called. This cylinder moves concentric to another, *i*, *i*, which is fixed, and against which it rubs at its upper border, which is furnished with a shield of leather, that prevents the passage of the water when the annular-gate is let down upon the fixed plate, *e*, *e*. Whilst, on the contrary, if we raise the movable cylinder, or annular sluice-gate, *g*, *g*, the water runs out between its lower edge, and the plate, *e*, *e*, and can then enter within the wheel.

The curved guides, *f*, *f*, are placed in such a manner, that the water enters the buckets of the wheel without sensible shock, and the liquid, receiving on these, a corresponding motion, is directed on the side contrary to the general running motion of the wheel; it results from

Fig. 1.

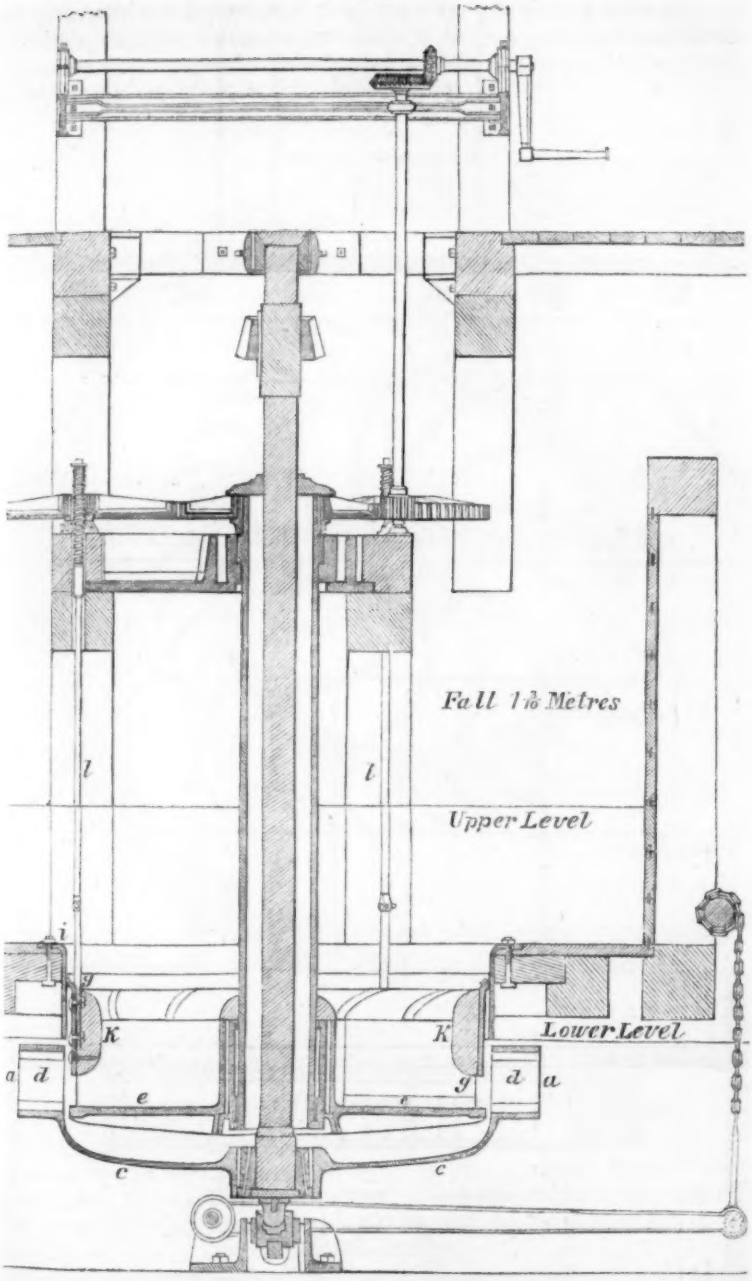
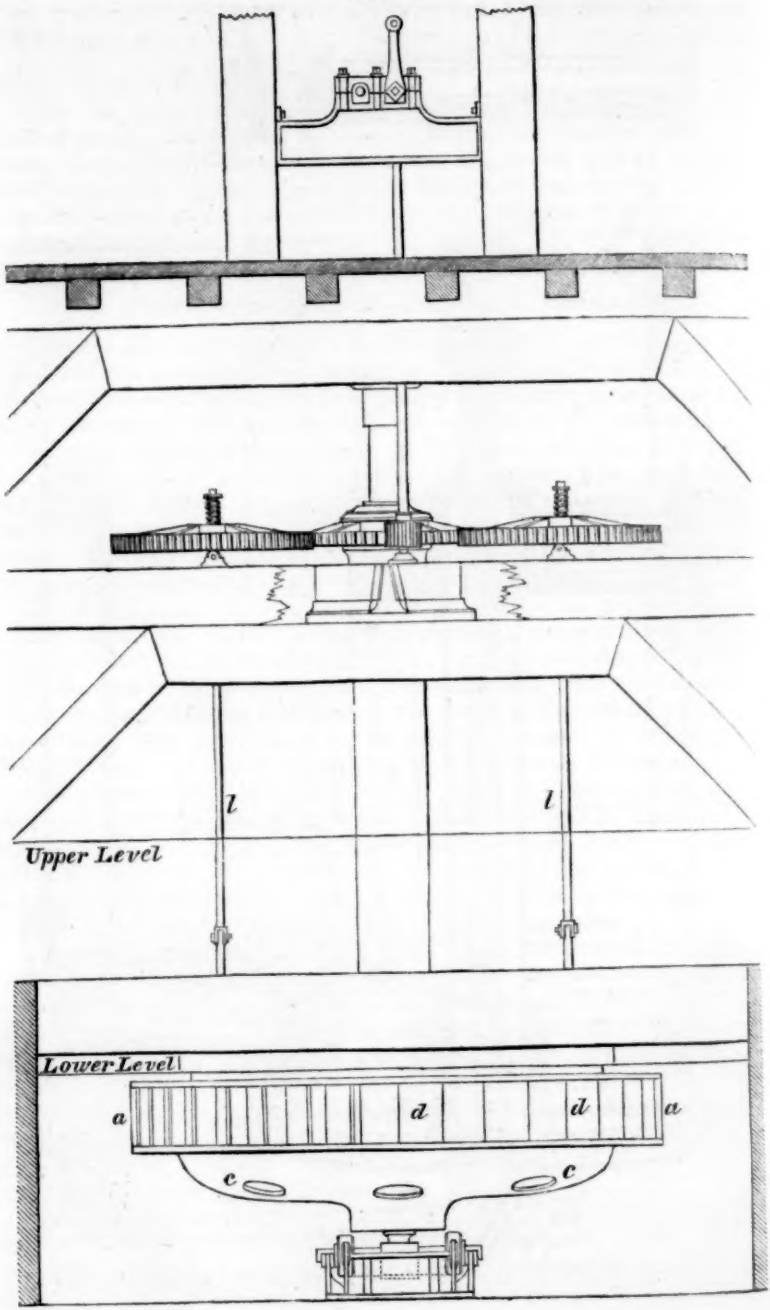
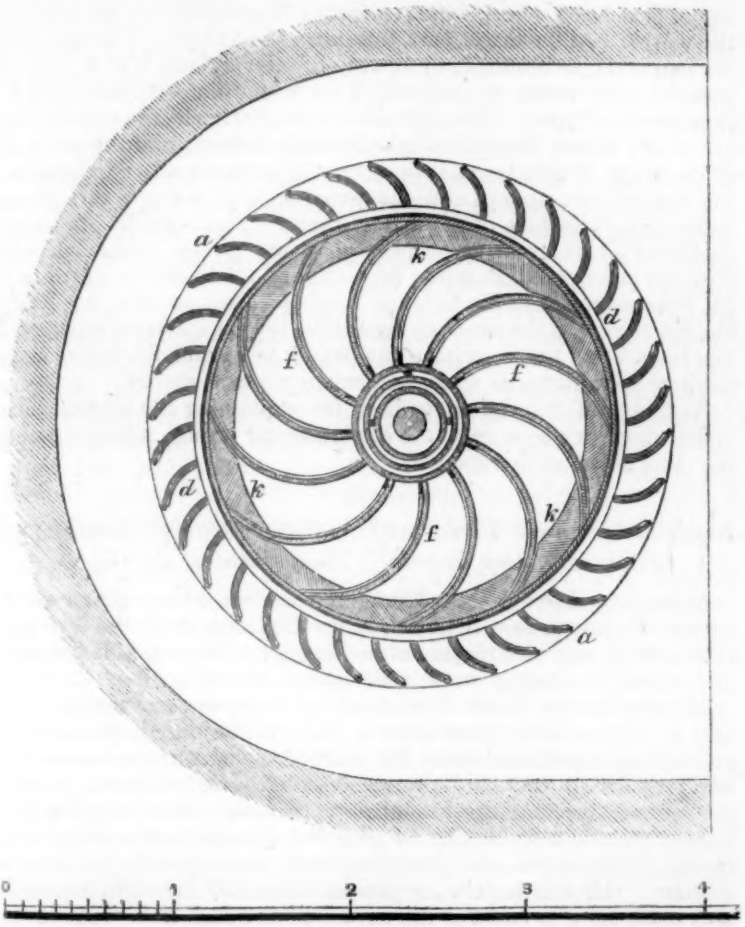


Fig. 2.



the proportions adopted, and from the ratio established between the velocities, that the water enters nearly without shock, and issues with almost no velocity, which satisfies, as we know, the general condition of the maximum effect in hydraulic motors.

Fig. 3.



Scale of 25 millmetres to a metre.

The *wooden cushions*, *k*, *k*, fixed to the *sluice-gate*, and slipping between the curved guides, diminish by the rounded form of their lower parts, the effects of contraction, which is, in consequence, nearly destroyed, or at least, very much diminished, on the four sides of the opening.

The motion is transmitted to the *sluice-gate* by *three vertical stems*,

or rods, l, l, **cut into screws on their upper parts, and around which turn three pinions, all of the same diameter, which act as screw-nuts, and are put in motion by a wheel concentric with the vertical pipe which surrounds the *main shaft*. This ingenious arrangement insures parallelism of motion in the *sluice-gate*.**

The *main shaft* passes through the hollow pipe, and has, on its upper part, a cog wheel, which transmits the motion into the interior of the works. At the lower part, this *main shaft* rests in a socket, which we can raise, as required, by the aid of a lever, and which, by an ingenious contrivance, is continually fed with oil, notwithstanding it is immersed in water. The lightness of these wheels, the constant supply of oil, which lubricates the rubbing surfaces, and the proximity of the water which keeps it from heating, remove all apprehension of the pivots wearing out, and the experience of many years demonstrates the excellence of the arrangement. The *turbines* producing a useful effect as great, in proportion to the power expended, when they are submerged, as when they are not, as we shall see further on. M. Fourneyron is in the habit of placing them, so that the level of the upper ring is the same as that of the lowest waters of summer; so that they, at all times, render the whole fall available, which is particularly advantageous at seasons when water is scarce.

As this brief description suffices for explaining the general action of the wheel, we pass on to the experimental results which constitute the chief object of this memoir.

V.

Experiments on the Turbines of the Power Weaving Establishment of Moussay, near Senoues (Department of the Vosges.)

Summary description.—There was established in 1836, in the village of Moussay, near Senoues, in the Department of the Vosges, a Power Weaving Establishment belonging to Messrs. Ed. Laurent & Co., which was put to work in the spring of 1837.

My duty having led me at this time into these works, I availed myself of it to request of the proprietors of this establishment, permission to make some experiments with this motor, from which to deduce its effect. My proposition was cordially received by these intelligent manufacturers, and they had the kindness to make all the arrangements necessary to mount the *brake, or friction dynamometer*, which I sent them. Their works, and their workmen, were liberally placed at our disposal. M. Fourneyron, in person, answered the invitation which was made him, to assist in the experiments; and it is with his aid, that they have been made. The manufacturers and engineers of the neighborhood came to witness, and lend us their assistance in the observations; *they were, consequently, made, and verified, by many persons.*

The motor of the works is a *turbine* of (0.85m.) $2\frac{79}{100}$ feet in exterior diameter, of which the vertical shaft transmits the motion directly to the lying shaft of the weaving mill, by means of a single beveled cog wheel. The water reaches the works by a canal of about (3 m.) $9\frac{84}{100}$ feet broad, and of a regular form, which conducts it into a prismatic

reservoir of (5 m.) $16\frac{4}{10}$ feet broad, into which opens a large vertical pipe, communicating by a very short horizontal pipe, with the cylinder which contains the *sluices* of the *turbines*. This cylinder, in which the *sluice-gate* moves, is closed at its upper part, and traversed by the vertical shaft, of which the extremity is of such a height as to allow the lying shaft of the workshop to pass a little below the ceiling of the ground floor. In this way, although the total fall is about $26\frac{38}{100}$ feet, the transmission of the motion is made, in consequence, at any suitable height without hindrance.

VI.

Arrangements adopted for the Experiments.

The *brake, or friction dynamometer*, composed of a cast collar of (0.80 m.) $2\frac{62}{100}$ feet in diameter, turned on its outer circumference, was put on the same shaft as *the turbine*, and the lever, placed horizontally, was supported at its extremity by a cord (6 to 7 metres) $19\frac{60}{100}$ to $22\frac{97}{100}$ feet in length attached to the wood work, in order that it should not bend by its own weight. Over a fixed pulley, placed in a direction perpendicular to that which this lever should preserve whilst it was in equilibrium, passed a leather strap to which was suspended the box that contained the load of *the friction dynamometer*. To make sure that the lever and strap should preserve a perpendicular direction during the experiments, we suspended to a fixed point, a plumb line, below which the middle line of the lever was to be constantly maintained. The perpendicular let fall from the axis of the wheel on the direction of the strap, or the arms of the lever of the load was (2.505 m.) $8\frac{22}{100}$ feet in length.

To insure regularity of friction, we kept the cushion of the *friction dynamometer* constantly wet, in order to maintain the surfaces in the same state of humidity. In consequence of this precaution, the lever remained almost constantly below the vertical of the plumb line, without the oscillations exceeding the space of $\frac{13}{100}$ to $\frac{16}{100}$ of a foot, and without any blows having occasioned violent shocks, as commonly happened when the state of wetness, or oiliness, of the surfaces varied. It also resulted from this continual wetting, that we had not to employ grease in these experiments, and that the temperature of the surfaces in contact, was not elevated even in the greatest velocities, beyond moderate limits, and that to cool them, it was only necessary to continue wetting them during the occasional interruptions in passing from one series of experiments to another.

VII.

Gauging of the volume of water expended.

It was indispensable to give the utmost possible precision to the means employed for gauging the discharge of water through the orifices of the *turbines*, and it would have been troublesome to establish a stop-gate in the tail-race, which is arched, and of considerable depth, but the feeding-race offering, for that purpose, every facility, we placed at its end nearest to the works, a stop-gate with a waste-board of (2.682 m.) $8\frac{80}{100}$ feet wide, of which the vertical edges (of the over-

fall) distant (0.28 m.) $\frac{82}{100}$ of a foot from those of the canal, had sharp angles, as well as the sill (or edge of the waste-board,) which was (0.60 m.) $1\frac{97}{100}$ of a foot, at least, from the bottom of the canal. The water, consequently, did not reach the reservoir, or *trough*, leading to the wheel, until it had passed over the waste-board, the lower edge of which was never flooded by back water during the experiments.

This arrangement lost part of the fall, and reduced it for the experiments to about (7.50 m.) $24\frac{61}{100}$ feet, ($1\frac{77}{100}$ feet being lost in the clear fall over the waste-board, necessary to render it *a correct meter*.—Tr.) this loss was not productive of inconvenience for the experiments in general; but to be able to make some under the full fall which the works could employ, we subsequently dispensed with the stop-gate, and calculated the expenditure of water by the aid of observations, made during the first series of experiments, proceeding in the following manner.

VIII.

Calculation of the volume of water discharged, based upon dimensions of the openings of the Turbines.

The sum of all the shortest distances measured between the side of one curved guide, and the reverse of the adjacent one, being (0.689 m.) $2\frac{26}{100}$ feet, and the lift of the sluice-gate being known for each experiment; we thence easily deduce the sum of the areas of all the orifices by which the water issues, and, consequently, (knowing the head,) the theoretical discharge. By comparing this theoretical discharge with that calculated from the experiments made with the waste-board, we have deduced for each lift of the sluice-gate of the turbine, the coefficient of discharge belonging to the orifices.

For calculating the discharge of water made by the waste-board, we have used the formula,

$$Q = 0.405\ LH\sqrt{2gH}$$

where,

Q = Quantity in cubic metres delivered per second.

L = Length of the opening of the waste-board in metres.

H = Depth of the edge below the surface of the reservoir in metres.

We resolved to adopt this formula, because, first, the sides, or borders, of the overfall, were at the distance of (0.25 m.) $\frac{82}{100}$ of a foot, at least, from those of the canal; second, the contraction was almost complete on three sides of the opening; and, third, some part of the furniture of the sluices allowed the escape of a little water which did not act upon the *turbine*. It seems to us, in consequence, that in adopting for the overfall the coefficient 0.405, we have estimated the discharge rather above, than below, the real value.

The following table contains the results of the comparison of the theoretical discharges computed from the dimensions of the orifices of the *turbine*, with the actual discharge calculated by the above formula.

Comparison of the actual with the theoretical Discharge made by the Orifices of the Turbine of Moussay.

No. of experiments.	*Sum* of the Areas of the Openings.	*Charge* of water, or difference, of the upper and lower levels.	*Discharge of water in one second.*		*Ratio* of the effective discharge, to the theoretical discharge, or coefficient of the discharge.
			Theoretical.	Actual.	
	Sq. Metres.	Metres.	Cub. Metres.	Cub. Metres.	
1	0.0344	7.091	0.405	0.363	0.892
2	0.0337	7.056	0.396	0.362	0.914
3	0.0320	7.160	0.379	0.362	0.954
4	0.0344	7.255	0.411	0.372	0.904
5	0.0344	7.229	0.408	0.364	0.890
6	0.0344	7.131	0.407	0.363	0.892
7	0.0344	6.927	0.402	0.349	0.869
8	0.0324	7.127	0.383	0.373	0.975
9	0.0330	7.313	0.395	0.349	0.884
10	0.0330	7.239	0.393	0.360	0.915
11	0.0330	7.294	0.394	0.351	0.890
12	0.0330	7.134	0.390	0.351	0.900
13	0.0330	7.034	0.388	0.345	0.889
14	0.0330	7.854	0.382	0.348	0.910
15	0.0324	7.395	0.390	0.378	0.970
16	0.0351	7.375	0.422	0.389	0.915
17	0.0351	7.087	0.413	0.375	0.909
18	0.0344	6.911	0.401	0.366	0.910
				Mean,	0.910
19	0.0517	7.278	0.617	0.523	0.848
20	0.0495	7.333	0.593	0.534	0.889
21	0.0544	7.105	0.640	0.540	0.842
22	0.0503	7.285	0.602	0.540	0.896
23	0.0503	7.150	0.596	0.515	0.864
24	0.0489	6.951	0.570	0.523	0.918
25	0.0489	6.986	0.571	0.520	0.910
26	0.0489	7.017	0.573	0.522	0.909
27	0.0489	7.019	0.574	0.512	0.891
28	0.0489	7.002	0.573	0.458	0.799
29	0.0489	6.994	0.572	0.512	0.894
30	0.0489	7.046	0.575	0.515	0.895
				Mean,	0.880

IX.

Deductions from the results contained in the preceding Table.

We see by this table, that the coefficient of discharge, which, for a lift of the sluice-gate of (0.050 m.) $\frac{16}{100}$ of a foot, is at a mean equal to 0.910, reduces itself to 0.80, when the lift is made equal to (0.071, or 0.073 m.) $\frac{23}{100}$, or $\frac{24}{100}$, of a foot. This diminution is one consequence of the arrangement of the orifices of emission, which do not occasion much contraction either on the bottom, or on the vertical sides, and of which the upper side is furnished with a cushion of wood rounded on its inner angles, which gives its proper direction to the fluid vein before it reaches the orifice. For the smallest lifts of

the sluice-gate, much inferior to the width of the cushion, the filaments issue horizontally, and do not undergo, at the sides, any other contraction than what proceeds from the convergence of the curved guides, so that this orifice is analogous to that of the conical, or pyramidal adjutages, (see page 235) and it explains how the coefficient of the discharge can become as great as 0.91.

In proportion as the sluice-gate is raised, the cushion having less influence on the direction of the fluid filaments, the contraction on the upper side of the orifice is not so completely annulled, and, therefore, the coefficient of discharge gradually diminishes with the lift of the *sluice-gate*, until that lift becomes equal to the height of the *turbine*.

We shall see farther on, by the observations made on the *turbine* of Mülback, that this induction is completely verified.

These observations accounting very well (as it seems to us) for the variations of the coefficient of discharge of these orifices, enable us to calculate by interpolation, the value of the coefficient of the discharge, in the cases where the lifts of the sluice were (0.86, and 0.107 m.) $\frac{28}{100}$, and $\frac{35}{100}$ of a foot, with which only we have worked, whilst omitting the gauge by the overfall, or waste-board.

In making the calculations, we have assumed, that within limits as narrow as those of our experiments, the decrease of the coefficient was proportional to the difference of the lifts of the *sluice-gates*, which evidently could not lead to any appreciable error. It is upon this basis, that we have adopted for the coefficient of the discharge corresponding to a lift of the gate of (0.086 m.) $\frac{28}{100}$ of a foot, the value of 0.86, and for a lift of (0.107 m.) $\frac{35}{100}$ of a foot the value 0.83.

(To be continued.)

Mr. Vignoles' Lectures on Civil Engineering, at the London University College.

[Continued from Page 174.]

SECOND COURSE—LECTURE XIV.—WORKING EXPENSES OF RAILWAYS.

Mr. Vignoles commenced by reminding the class, what he hoped they duly felt, that the great object he had in view during the present course, was to consider, in every bearing, the proportion between the cost and expenditure upon any work, as compared with the probable profitable returns. Although this consideration, and that of the good result of any such speculations, might be thought not to come strictly within the duties of an engineer, and, until of very late years, had been neglected, and, in some striking cases, absolutely repudiated, by eminent men, yet Mr. Vignoles was of opinion that it must ever be kept in view, and should absolutely form a branch of the engineer's study, for he ought to feel that any works he may be called on to construct, should not only be such as will reflect credit on him as a professional man, for design, arrangement, and execution, but, as the Professor had often urged, such as, in this commercial country, where private enterprize and speculation attempts, and effects so much,

will, by their success, prove the accuracy of his judgment, and his capacity, as an adviser, to lead spirited undertakers into future operations of the same kind. In short, that the success of an engineer depends, perhaps, more on the beneficial results of his works to the proprietors, as commercial speculations, than on his own masterly conquest by art over natural difficulties. But the engineer should further look at this subject in a higher point of view, and consider that all unprofitable expenditure is so much waste of the resources of a country, and that, of all professions in society, his is the one most called upon to direct the laying out of large sums on what may truly be considered national objects, for the judicious and beneficial results whereof he is responsible, and, consequently, whereon his reputation must ultimately depend. Referring to an expression in a late lecture, the Professor observed, that he by no means intended to represent that it was not necessary, in the construction of railways, to reduce the natural undulations of a country to uniform inclinations, but that it was to be maturely considered at what cost such advantage is to be acquired, keeping constantly in view a comparison of this cost with the working expenses of a line more or less perfect. It was the investigation of these *working expenses* that was now to be entered on. In proceeding to do this, Mr. Vignoles observed that he considered it by far the best way to reduce to a mileage, not only their gross sum, but also each of the items, these being again subdivided as far as possible. By a "mileage," he understood the result arising from dividing the periodical amount of the expenses by the total number of miles run by locomotive engines *with trains after them*. The Professor insisted that this was the proper way, and gave a number of reasons for his opinion, and for not at all considering the expenses with reference to any proportion they might form of the gross receipts—the two sources of income and expenditure being perfectly independent of each other; and Mr. Vignoles further thought this mileage comparison was the only one from which correct results could be drawn, and whereby materials and experience might be collected, so as to result in the practical benefit of companies being able, before long, to enter into contracts for most of the items of expenditure at given rates. Some companies had already contracted with each other for the supply of locomotive power, carriages, &c., at a mileage; the maintainance of the way was now almost universally paid for by the lineal mile of rail, and he had no doubt, but that, after a little more experience, other of the working expenses of railways would form subjects of such a kind of contract.

Mr. Vignoles then proceeded to enumerate the general heads of these expenses, viz., 1, *locomotive power*, subdivided into drivers' wages, fuel, oil, hemp, &c., ordinary repairs, water, and fuel stations, reserve fund; 2, *carriages;* 3, *maintenance of line;* 4, *police;* 5, *conducting traffic and stations;* 6, *rates and taxes;* 7, *government duty;* 8, *miscellaneous charges;* 9, *management.* These were the proper items, exclusive of interest on loans, which, although to be deducted before a dividend could be made, of course, formed no part of the positive working expenses of a railway. The Professor then

went into a minute analysis of these several items, as actually disbursed on certain railways of various lengths, and, particularly, of various gradients, explaining the reasons of excess, or of diminution, in one, or other, item on the respective lines, exhibiting also comparative tables, and making many valuable observations upon obtaining the best attention, and greatest economy from the servants of a public company, by instituting premiums graduated in proportion to the diminution of annual working expenses.

Locomotive power.—In considering this item, Mr. Vignoles showed, from an average of a number of lines, where the arrangements were properly established, and the railway had been long enough at work to have got all matters systematically arranged, the subdivision per mile per train might be taken as follows—viz., wages, 2*d.*; fuel, 4*d.*; oil, hemp, &c., 1*d.*; making 7*d.* per mile as the mere cost of motion, exclusive of repairs of any kind. This might be considered as applicable to an average of six or eight carriages per train. Heavier trains only came occasionally in the course of the 24 hours, and unless upon lines having exceedingly favorable gradients, auxiliary engines were then applied, the cost and mileage of which being included in the annual accounts, the above rate of calculation would still apply. On railways not having a very considerable traffic, the number of carriages, on the average, were fewer than above stated, and the engine and tender might be fairly taken as constituting half the gross load of each train. The items of wages, and oil, hemp, &c., would not materially vary on different lines, except, perhaps, the first, or on short lines with very great traffic, with quarter, or half-hour, trains, such as the London and Greenwich Railway, the Dublin and Kingstown, &c. The fuel would be a variable quantity, but it would rarely exceed 6*d.* Next must be taken the ordinary repairs, and the Professor stated that in no case was the old adage of "a stitch in time" so applicable, as in a constant vigilance, and daily inspection, and remedy, of the smallest defect in locomotive engines. A plentiful stock of engines of the very best materials and workmanship, and an efficient and roomy repairing establishment, though somewhat costly at first, would be found to be the means of keeping down the expense of repairs to a low figure. The amount of this item spread over a year's working appeared to average, on well regulated lines, about 7*d.* to 8*d.* per mile; some instances had been as low as 6*d.* The expense of water and fuel stations varied from ¼*d.* to ½*d.* per mile. The reserve fund was an arbitrary charge; Mr. Vignoles assumed that about 10 to 15 per cent. on the ordinary repairs would be sufficient—say 1½*d.* Thus it would seem that the total cost of locomotive power ought to be about 15*d.* or 16*d.* per mile per train. In some instances it had been reduced so low as 1*s.*; in others this amount had swelled to 18*d.*, and even up to 2*s.*

Mr. Vignoles then analyzed the other heads of the working expenses—viz., carriages, which he seemed to consider an expensive item, varying from 4*d.* to 6*d.* per mile per train—say from ¼*d.* to 1*d.* per carriage per mile, including the various descriptions of vehicles for passenger traffic. The maintenance of the railway varied most

remarkably, from 2*d.* per mile per train (which had been the cost on the Dublin and Kingstown Railway and was now even lower, and Mr. Vignoles believed that on the Greenwich Railway this was also a small item, since they had replaced their stone blocks by timber supports), up to 1*s.* per mile per train, which was the cost on several lines; but, on a railway with the upper works properly constructed, he thought that 6*d.* to 8*d.* per mile per train ought to keep a double road in good order, including a reserve, or depreciation, fund for renewing the iron rails—a contingency that should by no means be lost sight of. The Professor here made a long digression on this item, as to how much of the cost should be assigned to atmospheric causes, and all collateral and contingent circumstances; how much to the mere dislocation of the upper works; and how much to the positive wear and tear of the iron; and pointed out some remarkable instances of saving in maintenance, where the longitudinal timber bearings had been adopted. The charge of police varied from 1*d.* to 6*d.* per mile per train, according to the vigilance exercised; in placing 2*d.* per mile as an average, it was to be considered only as an approximation. Conducting the traffic and stations was an item that did not seem to differ much on the various lines; for the passenger department it appeared to be about 5*d.* Local rates and taxes would, of course, vary materially; the poor rate formed a serious charge on all railways; this item was indirectly contingent on the actual profits of the company; it appeared, however, to be seldom less than 3*d.* per mile per train. Government duty had heretofore been computed at ½*d.* per passenger per mile—henceforth it was to be calculated at 5 per cent. on the gross receipts for passengers only. This would, of course, make greater discrepancies; still, as the new duty on the gross was estimated to be equivalent to the old duty, an account might be obtained if the number of passengers per train were known. Assuming this number to average forty, taking all the railways of the United Kingdom, the government duty might be estimated at 5*d.* per mile per train. Taking a mean of four or five railways, the miscellaneous expenses were found to be about 2*d.*, and the management about 3*d.* per mile per train. Now, to make a summary of all these, which was, however, to be taken generally, and, of course, liable to be effected in the details, but was still interesting to be submitted in a popular form, and might be useful as giving a comprehensive view of the system;

Abstract of the average working expenses of a railway per mile per train.

	s.	*d.*
Locomotive power—viz., wages, 2*d.*; fuel, 4*d.*; oil, hemp, &c., 1*d.*; ordinary repairs, 7*d.*; water and fuel stations, ½*d.*; reserve fund, 1½.,	1	4
Carriages,	0	4
Maintenance of line,	0	8
Carried over,	2	4

	s.	*d.*
Brought over,	2	4
Police,	0	2
Conducting traffic and stations,	0	5
Local rates and taxes,	0	3
Government duty on passengers,	0	5
Miscellaneous expenses,	0	2
Management,	0	3
Total,	4	0

Mr. Vignoles did not, by any means, pretend that this was other than a probable approximation. Some lines had been worked at a lower rate per mile per train, including all the above expenses; for example, the latest accounts of the North Union Railway, show the cost to have been only 3*s.* 4*d.*, not including any funds for reserve. The Professor himself thought that 3*s.* was a fair sum, exclusive of taxes and duty, which, however, together form a large proportion of the expense. On the other hand, there were instances in which the expenses had gone up to 5*s.* per mile per train. He considered it would be a great public benefit if all railway companies, in their reports, would give fuller details of the working expenses, and state the number of miles run *by trains*. Some few Boards set a very good example in this respect. This was sometimes done for locomotive power, but the miles should only be computed as actually run with the trains, and not to include the various extra distances passed over in manœuvres, piloting, signals, &c., which though necessary, were not part of the actual mileage of trains.

The Professor then drew the attention of the class to the fact, that the locomotive power formed about one-third of the gross expense, and of that one-half only is likely to be affected by the gradient, or load, being only one-sixth of the whole of the working expenses, which was but a small item upon which a saving was to be made, to justify a railway being constructed theoretically perfect, unless the traffic was likely to be continued, regular, and very heavy. He further observed, that though he had proposed, for the sake of an easier comparison, to reduce all the items of the working expenses of a railway to a mileage per train, it was manifest that a considerable addition to the number of trains daily, and, of course, to the number of miles run, would very materially affect the locomotive power only. The taxes would be contingent on the receipts; and all the other items would be increased but in a very small degree, on the annual totals, by an increase in the number of the trains, with a carriage or two less at a time. It was important to remember this, as it affected greatly the question of laying out railways. Mr. Vignoles insisted that the extension of railways in England, especially in remote districts, would not be carried into effect until this subject had been more closely analyzed, and had become better understood. Looking at the practical working of the Newcastle and Carlisle, the North Union, the Manchester and Leeds, the Sheffield and Manchester, as

far as opened, and other lines, all having very heavy gradients, and contrasting their working expenses with those of lines whose inclinations were much more favorable, the average cost per train per mile did not vary greatly. Lines which had been formed at a cost of from £50,000 to £60,000 per mile, a large portion of which was to obtain perfect gradients, seemed to require little less to work them than lines costing only one-third to one-half that sum. It is true they might be able to carry heavier trains, and did so carry them occasionally, but the average was very nearly what had been stated, and, besides, the public were best accommodated by lighter trains going more frequently. The Professor said, he could only hope that his arguments would draw attention to the subject, and that when, after the analysis of the cost of all the railways had been brought out in the way shown in his last lecture, and that of the working expenses, as in the present one, materials would be obtained for the solution of the problem, of what must be the rule for constructing lines of passenger railways hereafter.

(To be continued.)

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

On the Injury done to Roads by the Passage of Carriages.

An able report* has lately been made to the French Chamber of Peers, by the Minister of Public Works, M. Teste, on the maximum load which carriages should be allowed to draw on the roads constructed by the government. In contains, as its basis, a clear and minute account of a series of experiments, performed by M. Morin, during a period of several years, to ascertain the manner in which the injury done to roads, by the passage of vehicles, depends upon the dimensions of those vehicles, and on the loads which they carry. These experiments are not yet generally known, and they seem so valuable, on many accounts, to both the engineer, and the machinist, that some extracts from the report of M. Teste, may be acceptable to our readers.

But besides the experimental results themselves, and apart from the subject upon which they directly bear, there is one point suggested by the reasoning of M. Morin, of so great interest, as to warrant an extended notice. This is the relation between the deterioration of roads, and the resistance to the motion of carriages, or, to state it in a more general form, between the injury, and the contemporaneous friction. The evident advantage in almost every department of the arts, of the determination of this relation, is sufficiently obvious; but the inquiry assumes a graver importance from the singular and violent contradictions which it discloses between the received laws of friction, and the facts which have been observed. Whenever such differences occur, it is natural to wish to reconcile, or explain, them, and this becomes absolutely necessary in a question of such immediate, and practical concernment as that of friction. As the limits, however, of

* Addition à la Séance de Mercredi, 10 Mai. Moniteur 14 Mai, 1843.

a prefatory notice will not admit of a complete solution of this problem, we can do scarcely more than submit to the consideration of engineers, a purely theoretical formula, which both explains the anomalies hitherto observed in the laws governing the attrition of bodies, and contains the relation between the deterioration, and the friction, of which we have spoken.

It is, in the first place, evident that the injury done to any body by the action upon it of any other body moving over it, must be proportional to the force, or power, expended in producing it. This force is of two kinds—one, a part, or a function. of the force of gravity, or the weight, of the moving body; the other, the force necessary to overcome the resistance in the direction of the motion, occasioned by the inertia and cohesion of the opposing particles of the stationary body, and to tear them off, or separate them. Representing the first force by fP, and the second by R, we shall have for the expression of the injury, M (fP+R), M being a coefficient depending upon the nature of the rubbing surface. But if we should adopt a very common opinion as to the cause of the friction, and believe it to be solely the opposition of the projecting particles of the surface, upon which any body moves, so that these particles must be broken off, and cast aside, in order to admit of motion, we shall evidently have, as a formula, for the friction, F = R. Now, it is perfectly plain, that whenever M and fP are constant, any increase, or decrease, in the injury, must take place in the term R; R, therefore, will, in this case, vary when the injury varies, and, consequently, the friction which is equal to R, will vary when the injury does. But the experiments of M. Morin, in 1837, will be seen, hereafter, to prove that the injury increases when the velocity increases; the friction then should likewise increase with the velocity, and yet M. Morin has shown, from his experiments in 1831, reported in the Memoirs of the Academy of Sciences, for 1833, and since in this Journal,* that the friction does not change with any alteration in the velocity.

Here, then, occurs that violent contradiction between theory and experience, to which we have alluded—a contradiction only to be explained by the insufficiency of the one, or the incompleteness and inaccuracy of the other. It is most natural to suppose that the theory is defective, and that some other cause concurs in producing friction besides the mere resistance of the particles of the rubbing surfaces. If this is actually the case, the expression for the friction will no longer be R, but of the form X + R, and then it is evident that an increase in the value of R so great as to cause a very marked variation in the injury, may only occasion an almost imperceptible increase in the friction, so that it might easily be overlooked by experimenters.

To discover, then, this additional cause, or, perhaps, causes, and to derive from thence a complete theoretical equation for friction, let us suppose that the body A, is drawn over the body B; that the friction is to be measured by the force of traction continually necessary to maintain an uniform motion; and, finally, that B is of such hardness, or consistence, that A cannot sink farther than its own height into B. The definition given to the friction, is the one generally used, and the

* Vol. x; 2nd, series, p. 285.

last supposition is made solely to simplify the question. Now, there may be, and there usually are, with the substances in common use, three different causes of friction, or, of the resistance to motion—one already mentioned, the direct opposition of the particles of the body B, which A, in its motion, tends to break off, or plough up, or divide, in order to move; the second, the resistance occasioned by the shocks which the roughnesses of B must produce, if they do not give way to A; and the third, that disclosed by the elegant hypothesis of Euler, (Mem. Berl. Acad., 1748, p. 125,) an hypothesis, which, like most of the works of that great mathematician, has been too much neglected by subsequent theorists. We shall consider these separate causes in the inverse order to that in which they are named.

The conjecture of Euler is somewhat similar to that of M. Parent, but much more simple and natural. It consists solely in supposing that the little projections, or roughnesses, which exist on the surface of every body, form a complete succession of inclined planes, up which one body moving over another must be forced. Now, it is perfectly evident, that more power will be needed to draw a weight up an inclination, than along a perfectly level surface, and this additional power required, is, according to Euler, the whole of the friction. To make this clearer, imagine the plane B, to be placed horizontally, and made perfectly smooth and hard, (for, although this is not possible in reality, it is so in imagination,) and let the body A be drawn over it: it will at once be seen that there can be no resistance to the motion, and that any, the least, power will be sufficient to move it. Imagine again, that B, although still remaining perfectly hard, is not entirely smooth, but covered with a succession of minute, and similar elevations, or inclined planes. The whole resistance now will amount to the force necessary to compel A, resting itself upon small projections of its own, to ascend any one of these little inclinations of B.

The power, then, required to move A forward, or the resistance, or the force of traction, or the friction, for these are all equal in quantity, will depend, in the first place, upon the weight of A, or upon P; in the second, upon the nature and form of these minute elevations. It may, therefore, be represented by C.P, in which expression, C is a variable function of the nature of the substance of the body B. As we shall hereafter see that this expression does not represent the whole of the friction in all cases, nor, indeed, in general, we may designate the portion which it does represent, by F′, whence results the equation,

$$F' = C.P. \qquad (1)$$

When the body A has thus ascended one of the inclinations, the little projections of its own, on which it is supported, have to descend into the hollow between the similar projections of B, in the same way that cog-teeth fit into each other. In the course of this descent the force of gravity, and the velocity combined, drive the projections of A against those of B, and this shock acting obliquely to the direction of the motion, impedes the progress of A, and constitutes, therefore, a part of the resistance. It may be represented by D.P.v, where v is

the velocity of A and D, a variable function of the nature of the body B, and of the angle which the line of draught makes with the plane of B. We have, therefore, for the effect of the second cause of friction,

$$F'' = D.P.v. \qquad (2)$$

As the hypothesis of Euler, however, and the conclusions deduced from it, imply a degree of hardness in the body B, sufficient to enable its little projections to preserve their form against both the pressure of the imposed weight, and the shocks which they suffer, this hypothesis will not be sufficient to account for the resistance when B is composed of any yielding substance. To discover an expression for the additional friction produced in this case, we must resort to the supposition of another cause—the cause, in fact, which was mentioned at the outset.

Imagine, then, the plane B, to be composed of matter not possessing cohesion enough to prevent the body A from sinking partly into it. According to this hypothesis, A, in its motion, will tear up, and either carry alon gwith it, or cast aside, some part of B, and the power expended in doing this, is evidently equal to that part of the friction which is due to the direct opposition of the particles. In order to estimate its amount,

Let h represent the force of cohesion of the material of B, or the weight which B can support upon a square foot without yielding.

d, the depth, or thickness, of A.

b, the breadth.

mb, the length.

v, the velocity.

P' the weight pressing upon a square foot of the lower surface of A.

Then the friction arising from the cause just mentioned, will be proportioned:

First, to the depth to which A will sink into B. Let this depth be x, and x will depend upon the weight which causes the sinking. The weight on a square foot effective for this purpose, is the difference between the actual pressure P', and the quantity h, which B is capable of sustaining by virtue of its hardness; it is therefore, P'—h. If there was no other force to oppose this, and if P' were greater than h, the body A would sink entirely through B. But every substance in nature becomes more compact by compression, so as to be able to support weights indefinitely great. Suppose, therefore, that B increases in density, and hardness, in such a manner that its supporting power at any small depth as x, may be represented by $h+(fh)x^z$, (fh) being a function of h, and z, the exponent of the power designated by the law of the increase. We shall now have $h+(fh)x^z = P'$, or $x = \sqrt[z]{\frac{P'-h}{fh}}$. Introducing the value of P', or $\frac{P}{m.b.b.}$ the equation becomes,

$$x = \left(\frac{P-m.b^2.h}{m.b^2.fh}\right)^{\frac{1}{z}}.$$

In the second place, the resistance, or the friction, will be proportional to the force of cohesion h of the particles, which the body A has to tear apart in its motion forward.

In the third place, the resistance would vary exactly with the breadth b, (since the greater the breadth, the more particles must be torn up, and pushed forward) if it were not for one remarkable circumstance. When A has separated in its motion, the molecules of B, it generally throws them on one side, as a plough would do, else it would have to force along in front of itself, a strip extending the entire length of B. Now it is evident that the broader the front surface of A is, the more difficulty will there be in throwing the molecules completely to one side, and the longer will it take to do it, so that the number of particles which have to be carried along in front of A, before being thrown aside will increase, and, therefore, the resistance will increase with an increase in the breadth. The resistance is not then exactly proportioned to the first power of the breadth, but to something more, to b^{1+n}, b^{n}, representing the increase in the resistance arising from the circumstance just mentioned. In air, n has been found to be about $\frac{15}{100}$; in water, about $\frac{2}{10}$. In sand, which is a semi-fluid, it may, perhaps, be called $\frac{1}{5}$.

In the fourth place, the resistance varies with the first power of the velocity, when the definition for friction, which we have adopted, is used; for the greater the velocity of A, the greater likewise will be the force with which it strikes the particles of B, the greater, consequently, the reaction upon A.

Uniting these separate modes of variation, that part of the resistance, or friction, which is the result of the cause which we are now considering, will be represented by $\mathrm{E}.x.h.b.^{1+n}v$, E being a coefficient to be determined for each substance by experiment. Substituting the value of x, and reducing, we shall have the equation,

$$\mathrm{F}''' = \mathrm{E}.\left(\frac{\mathrm{P}-m.b.^{2}h}{fh.mb^{2-z-nz}}\right)^{\frac{1}{z}} h.v.$$

And making $z=1$, which is the most natural supposition at small depths.

$$\mathrm{F}''' = \mathrm{E}.\left(\frac{\mathrm{P}-m.b.^{2}h}{fh.m.b^{1-n}}\right).h.v. \qquad (3)$$

This equation represents the amount of friction derived from the direct opposition of the particles, to a force tending to break them apart, and plough them up. But in no substance, with which we are acquainted, and especially in no granular material, will this be the only cause of resistance to motion. For, suppose that the body A has sunk to any determinate depth in B, it will then rest upon a bed of minute molecular projections, or grains, or inclined planes, similar to those over which it would have to pass upon the surface of B, if it did not sink. Besides, therefore, the force necessary to push a bulk of matter before it proportional to the depth sunk, two additional forces must be employed, or expended—one, to draw A up these little

inclinations; the other, to supply the power lost by the shocks. Each of these forces is the measure of an additional portion of the friction, the first, as we have seen, being represented by F', and the second, by F'', so that the hypothesis of Euler, and the common one, are not contradictory, but equally probable, and they should be considered together, and not separately, when we would account for the effects of friction. We ought, then, to make the entire resistance from friction the compound, or sum, of these three resistances, which we have analyzed, and to establish for the final equation,

$$F = F' + F'' + F''' = C.P. + D.P.v + \frac{E.(P - m.b^2h).h.v.}{fh.\ m.b^{1-n}} \qquad (4)$$

It would exceed the limits of this article, to compare this equation in all points with experimental results, or to enter into the complex analytical investigation necessary to determine the values of the variable coefficients, C. D and E. It is sufficient that these contain no terms which can materially affect the conclusions which we wish, at present, to draw.

I. When $h = P'$, or $P = m.b^2h$, that is, when the cohesion, or hardness, of the surface of the body B, is sufficient to support the weight P without any alteration in its particles, the third term will vanish, as it is natural to expect, and then $F = C.P + D.P.v$, or rather inasmuch as on a comparatively smooth surface, and with small velocities, D.P.v will be very small, with relation to the first term, we shall find very nearly $F = C.P$, the second member of which contains no factor of the surface, or the velocity. The friction, is, then, proportional simply to the pressure, and this theoretical conclusion is abundantly confirmed by the experiments of Coulomb and M. Morin, with *hard* and *smooth* substances.

II. When $h = o$, inasmuch as the variable coefficients C and D must contain h as an implicit factor, the three terms vanish, and $F = o$, as in a vacuum, and approximately in the air.

III. When the quantity $m.b^2h$ holds, as in all yielding substances, an intermediate value between P and o, the friction will increase when the velocity increases, and will decrease with the breadth, or the surface; and this has been very clearly shown to be the case, by the experiments of Vince, Coulomb, Parent, Rennie, and those of Morin in 1838, upon bodies possessing little cohesion in proportion to the pressure. This conclusion, fortified by so many proofs, cannot be invalidated by the experiments of M. Morin in 1831, which were all made with comparatively *unyielding* materials. It is to be noticed, however, that the friction is not exactly proportional to the velocity, but to an expression of the form $1 + Mv$, where

$$M = \left[\frac{D.P + E(P - m.b^2h).h}{fh.\ m.b^{1-n}}\right] \div CP.$$

Hence, it is evident, that M must be very large, or that CP must be very small, compared with the value which $F'' + F'''$ obtains at a velocity of one foot per second, in order that the friction may be considered proportional to the velocity. But it is easily seen that with

hard bodies CP, is *greater* than the value of $F'' + F'''$ referred to, and therefore, it is nowise surprising that experimenters upon unyielding substances, have, of late, considered the velocity to have no effect upon the friction.

Having thus seen that the equation (4) is not only probable from theoretical considerations, but also confirmed in its most essential parts by experience, let us attempt to derive from it the relation which the injury done to any body B, by the motion of another body A over it, bears to the friction produced at the same time between A and B, and to this end, let us resume the reasoning which was employed at the commencement. An expression was there found for the injury, such that if we represent it by I, we shall have the equation, $I = M.(fP + R)$, or since, according to the definition there given for R, $F''' = R$, the above equation will become,

$$I = M.(fP + F''') \qquad (5)$$

and substituting the value of F''' in terms of F, F' and F'',

$$I = M.(fP + F - [F' + F'']). \qquad (6)$$

If the values of M, F' and F'', and the nature of the function of P can be determined for the substances in common use, we can likewise obtain the value of the injury I, directly from the measurement of the friction F, so that the wear of machinery, and the deterioration of roads and railways, may thus be estimated in a simple and expeditious manner. As the problem, however, under this general form, is somewhat too complicated for our present limits, let us consider the equation (5) as it becomes when the proper value of F''' is inserted, that is, when

$$I = M.\left[fP + \frac{E.(P - m.b^2h).h.v.}{fh.m.b^{1-n}}\right]$$

It will be seen by a little reflection, that $\frac{P - m.b^2h}{fh}$ is a factor of fP, so that this equation becomes,

$$I = M.\frac{(P - m.b.^2h).}{fh}\left[X + \frac{E.h\,v}{m.b^{1-n}}\right] \qquad (7)$$

X representing the other factor of fP. The injury, therefore, decreases when the surface $m.b^2$, or the breadth b increases, although not in exact proportion; it also increases with the velocity, and when X is 1, or of a value much smaller than $E.h$ (as it must always be), the injury may be considered as increasing proportionally to the velocity. These conclusions, it will be seen, are confirmed by the experiments of M. Morin.

The formulas thus far introduced, are applicable only to the case of prismatic bodies resting upon a plane surface; when the lower surface of the rubbing body is perceptibly curved, as in the case of wheels, some modifications must be made in the expressions for the friction and the injury, which may be briefly noticed. Suppose, in the first place, that the wheel does not roll, but is simply dragged along. The first term of the friction F', will not be altered, but the

second and third, F'' and F''', will receive a change; for the direction and force of the shock, represented by F'', will vary with the curvature of the striking body, and the coefficient D must, therefore, vary from the same cause, and, with regard to the third term F''', m is a function of the curvature of the increase of density fh, and of the weight upon a square foot P', so that it is only when all these remain the same, that F''' is unaltered.

Imagine, again, that the wheel is rolling. In this case, the modifications, noticed above, are still necessary, and with them some others, of which we need only, for the purpose of determining the deterioration of roads, specify that which takes place in the third term. It is not difficult to see that the part of the force of traction which corresponds to F''', must vary inversely with the diameter of the wheel, for this force acts at the axletree, while F''' acts at the circumference, so that the force referred to, is equal to $\frac{F'''}{\frac{1}{2}d}$. But this explanation does not at all imply that the real friction at the circumference, and, consequently, the injury is diminished by an increase in the diameter, although a little consideration of the subject will show that this is the fact. If a wheel was so low that the resistance from obstacles upon the road, should be in a direction passing through the centre of the axle; that is, if the centre should not be higher than the obstacles, no motion could take place, unless the wheel broke down what opposed it; but if we suppose that the radius of the wheel is increased, and the line of draught, thus made, to pass above the line of resistance, both a rotary and a forward movement would take place—the wheel, that is, would roll up, and surmount the obstacle. This effect would be more likely to occur, as the radius of the wheel was greater, and since it evidently amounts to changing the crushing and tearing action, represented by F''', into the motion up inclined planes, represented by F' and F'', it must cause a decrease in F''', proportioned to the probability of its existence, proportioned, that is, to $\frac{1}{2}d$, or one-half of the diameter of the wheel. The greater, therefore, this diameter, the less will F''' be in the case of rolling wheels, and the equation (5) will become $I = M.\left[fP + \frac{F'''}{\frac{1}{2}d}\right]$, whence, as before,

$$I = M.\frac{(P - m.b.^2h)}{fh}\left[\frac{X + H.h\,v}{d.m.b^{1-n}}\right] \qquad (8)$$

H, in this expression, is equal to 2E.

It has already been remarked that m is a function of the curvature, and, therefore, must change when the diameter changes. If we suppose it to increase with the first power of the diameter, it may be represented by sd, s being a coefficient depending upon the other causes of variation. By introducing this value of m, by making $X = 1$, and the exponent $n = \frac{1}{5}$, or $n - 1 = \frac{4}{5}$ (as is the case in sand or gravel), the equation (8) will become,

$$I = \frac{M.(P - sd.b.^2h].}{fh}\left(\frac{1 + H.h.v}{sd^2.b^{\frac{4}{5}}}\right) \qquad (9)$$

This is, then, an approximate formula for the injury done to roads by the passage of carriages. The most important of the consequences which may be deduced from it, seem to be the following: The injury *increases* with the load P, and the velocity v, although not in exact proportion to the increase of those quantities. The injury also *decreases* when the breadth of the wheel b, or when the diameter d, increases, although not in exact proportion.

These conclusions may be drawn from the simple inspection of the equation. Some of the less obvious results, are, that when several carriages travel, one exactly behind the other, those behind do scarcely any injury, in comparison with the foremost; that when several carriages are loaded with weights proportioned to the breadth of their wheels, those with the widest wheels will do the most injury; and, finally, that when several carriages are loaded with equal weights, the injury will not decrease as fast as the breadth of the wheels. All these theoretical conclusions are confirmed by the experiments of M. Morin, and this coincidence may be considered as a proof of the correctness of the formula. The accuracy, however, of the particular equations, which have been given, is not of so much importance as the soundness of the general method by which they are constructed. This method consists simply in the union of all the causes which can, in any way, contribute to the production of a certain effect, and the combination of the partial effects, which each of the causes would of itself produce, into one expression representing the real, or complete, effect. It is, in fact, an application of the theory of probabilities, the variable functions C, D and E. $\frac{(P-h)}{fh}$ representing, respectively, the probability that F', F'', or F''', will exist, or that the different causes of friction, which occasion those terms, will really act. How far this method may be employed with advantage in physical researches, is a question worthy of some consideration.

The foregoing observations and formulas, will, perhaps, do something to show the importance, in many points of view, of the series of experiments undertaken by M. Morin, by order of the Minister of Public Works, and may serve to clear up some points which those experiments left doubtful. The actual demonstrations of experience, however, are more quickly comprehended, and more easily applied, than any abstract conclusions,) and practical men, therefore, will like to see the results of investigations, conducted with the ability and care which distinguish all M. Morin's inquiries.

"Towards the end of the year 1838," says M. Teste in his report, "and when the last draught of a law upon the regulation of the transport of goods, already adopted in the Chamber of Peers, was about to be discussed, in the committee appointed by that of Deputies, an officer of Artillery, commissioned by the Minister of War, with the execution of some experiments on the traction of carriages, M. Arthur Morin presented a memoir, upon this question, to the Academy of Sciences. In that work, the author arrives at many conclusions, relative to the action exerted by vehicles upon roads, which are the only ones with which we shall here occupy ourselves." [These

conclusions were, in brief, the following: "The injuries produced by carriages upon roads, are as much greater as the wheels are smaller; (which is not altogether accurate) the resistance upon paved, or solid, macadamized roads is nearly independent of the breadth of the tire; upon such roads, also, even when they are in a very good state, the shocks occasioned by the inequalities of the ground, produce a loss of the velocity, and, consequently, an increase of the resistance, as much more remarkable, as the velocity is greater, and the carriage less elastic;" and, finally, "carriages without springs, going at a walk, injure macadamized roads more than carriages with springs, going at a trot."]

"Such were the principal conclusions as to the action of carriages upon roads contained in that memoir, which, when submitted to the judgment of the Academy of Sciences, had obtained the approbation of that illustrious Society, upon the report of a committee composed of M. Arago, Poncelet, and Coriolis, reporter. That work necessarily attracted all the attention of the administration of roads and bridges, as well as that of the committee of the Chamber of Deputies. The discussion, therefore, of the report of that committee, was adjourned to allow time to repeat and verify the results, and the conclusions announced.

"To arrive at this verification, the Minister of Public Works asked of his colleague, the Minister of War, that the author of the experiments should be attached to his department, for the special purpose of executing such others as should be judged necessary, according to a programme which had been requested from him, and a special committee of engineers of roads and bridges was charged with examining the successive results of the experiments.

"The experiments commenced in the month of March, 1839; their principal end being to discover the influence of the loads, of the breadth of the tires of the wheels, of the diameter, of the velocity, and of the springs, regard being had to the destructive effects produced upon gravel roads, the village of Courbevoie, (whence depart many solid macadamized roads, made of a siliceous gravel from the basin of the Seine, having all a thickness of 12 to 14 inches, at least, and having been put in a good state of repair,) was selected as a central point for the experiments. The general system of experimenting adopted, was the following: The carriages, whose injurious effects were to be compared, were drawn over portions of the same road, taken at the beginning in the same state. Each of them had its particular track, over which it ran, going and returning constantly upon the same route, in order to accumulate and multiply the injury to the road. When the weather was too dry, the tracks were watered, in order to maintain them at the same relative degree of moisture. Each day the committee noted the number of passages executed by the carriages, and took care, in each series, to regulate this number, so as to make the same weight, including the carriages, pass over each of the tracks.

"When, after the transportation of the same weight upon the tracks to be compared, (each of which was always more than one hundred

metres, per 109 yards in length,) the injuries were thought to be sufficiently increased to give approximate results, the intensity of the force of traction of the carriages upon each track, was measured with very accurate dynamometers, and by the comparison of the different intensities observed with each other, and with that of the traction upon the untouched road, the absolute and relative increase of the traction corresponding to the injury produced, could be appreciated. These trials were repeated many times, and when it was at last judged that the injuries were sufficiently advanced to allow a conclusion to be deduced, the experiments on the traction were repeated for the last time; the state of the different tracks was noticed, and transversal sections of the ruts were drawn, in order to compare them with the primitive state of the road.

To these three means of comparison, there was afterwards added the sum of the quantities of materials employed in the repair of the road, after the removal of the mud and the dust, which gave nearly the empty space formed by the ruts, or the amount of the materials of the road ground up and separated. Thus, the committee had four methods of observation for comparison, in order to appreciate the destructive effect produced by the carriages—the account of the state of the ruts—the drawings of the transversal sections—the measurement of the intensity of the force of traction—and the amount of the materials employed in the repair. The results of these four methods have always presented a satisfactory agreement worthy of inspiring confidence in the conclusions which have been deduced from them.

"In order to determine the part which each one of the elements in this complicated question played, care was taken to separate it from the others. Thus, when the committee wished to compare the effects of different breadths of the wheels, they employed carriages exactly alike as respects the diameter, and all other circumstances except the breadth of the wheels. In the same way they determined separately the influence of the diameter of the velocity, and of the springs.

"Each of the series of experiments required not less than 20 or 25 consecutive days, and it was not until the end of the year 1839, that the results could be discussed. The principal experiments, and the conclusions which their author has deduced from them, are the following:

"Three wagons, mounted each upon four wheels of the same diameter, but with tires whose breadths were 6.9, 4.5, and 2.4 inches, respectively, were loaded proportionally to the breadths, in the ratio of 550 pounds for one inch. After the passage of about 8000 tons over each of the tracks, it was found that the track of the carriage with the largest tires was the most injured, while that of the carriage with tires 4.5 inches broad, was also seen to be more affected than that of the carriage with tires of 2.4 inches in breadth. Hence, it was concluded that, 'when the loads are proportional to the breadth of the wheels, the carriages with the broadest wheels, cause the most injury to the road.'

"Another series of experiments, executed with the same carriages, loaded with *equal* weights, including the carriages themselves, showed

that, although it is incontestible, that wagons with narrow tires of 2.4 inches, do more harm to macadamized roads, than those with large tires, still there is little difference between the injuries caused by those with tires of 4.5 inches, and of 6.9 inches in breadth. This has confirmed the opinion announced in 1838, that there is not any remarkable advantage for the preservation of roads, in employing wheels more than 4.7 inches broad.

"The same wagons mounted upon wheels having a common breadth of 4.5 ins., and of the different diameters 2 ft. 10 ins.—3 ft. 11 ins.—6 ft. 8 ins., and loaded each with the same weight, 10,846 pounds, were drawn over three tracks upon the same road. After the transport of 9,741 tons, it was found that the wagon with the small wheels of 2 ft. 10 ins. in diameter, had produced the most considerable injuries, and that the wagon whose wheels were 6 ft. 8 ins., had only occasioned a trifling rubbing. Hence, came this conclusion, 'that wheels of a small diameter by the effect of separation of the particles of the road *(désagrégation)*, which they produce, do more harm than wheels of a great diameter.'

"Two post wagons exactly alike, and hung upon eight springs, were loaded, first with 13,200 lbs., and afterwards with 11,500 lbs. only. One of them whose springs had been wedged up, was drawn at a walk: the other, whose springs remained free, was conducted at a trot with the velocity of 8¾ miles per hour. After the transportation of about 4,534 tons upon each of the tracks of these wagons, it was found that the one ran over by the wagon on springs, was a little less injured than that of the wagon without springs, which went at a walk. Hence, came the conclusion, 'that carriages with springs going at a trot, can bear equal loads to those of carriages without springs, proceeding at a walk, without occasioning greater injury to a macadamized road than the latter.' The results of the experiments, also, having been the same from the commencement, when the road was in a good state, to the end, when the tracks had become very bad, the foregoing conclusion can be applied to all cases."

[This experiment is, perhaps, the most interesting and important of all which M. Morin made, because it is extremely difficult to determine *á priori*, the extent of the influence of springs, and we have hitherto had very few data by which we could form a judgment on this point. It will not be difficult now to find an approximate value for this influence. Let x represent the ratio of the force required to draw a carriage with springs, to that necessary to move at the same speed, the same carriage without springs. Then, if we suppose the speed with which the wagon, whose springs were wedged up in the foregoing experiment, proceeded, to have been 3¾ miles per hour, that part of its force of traction represented by $\frac{F'''}{\frac{1}{4}d}$ (eq. 8) was

$$\frac{15.H.(P-m.b^2.h).h}{4\ldots.fh.d.m.b^{1-n}},$$

and when mounted on springs, and going at the rate of 8¾ miles per

hour, its force of traction $\frac{F_1'''}{\frac{1}{2}d}$ would, consequently, be,

$$\frac{35}{4}\cdot\frac{4}{15}\cdot\frac{15}{4}\cdot\frac{H.(P-m.b.^2h).h.}{fh.d.m.b^{1-n}}X.$$

But since, according to the result of the experiment, $I=I'$, or

$$M.\left(fP+\frac{F'''}{\frac{1}{2}d}\right)=M.\left(fP+\frac{F_1'''}{\frac{1}{2}d}\right)$$

we must have $F'''=F_1'''$, and by substituting the values of these quantities just found, and reducing, it will appear that x is equal to $\frac{15}{35}$, or $\frac{3}{7}$. This, however, only represents the influence of springs in reducing the amount of F'''. To determine the entire effect upon the whole friction, we must observe that F'' is the only remaining part that is affected by the elasticity of the carriage, and that upon iron rails, F''' may be considered as vanishing, so that we there have $F=F'+F''$. Let us, also, suppose that these two quantities F' and F'', are equal to each other in this case, and further, that F', F'' and F''', upon a macadamized road, are also equal to each other. Now, it was found by M. Pambour, (Treatise on Locomotives, ch. iii, sec. 8,) that upon railroads $x=\frac{97}{100}$, whence it follows, that if F represent the friction of a railway carriage without springs, $\frac{97}{100}F=F'+\frac{94}{100}F''$. represents the friction with springs, and that $\frac{94}{100}$ is the factor by which F'' must be multiplied to show the effect of the use of springs. We shall find, therefore, that the resistance with springs in the case of macadamized roads, which we are especially considering, will be equal to Fy, or $F'+\frac{94}{100}F''+\frac{3}{7}\frac{F'''}{\frac{1}{2}d}$, whence $y=\frac{79}{100}$, and, therefore, by the addition of springs, the friction, or force of traction, necessary to draw a given load, is reduced to 79 per cent. of what it would have been without them. The suppositions which have been made to arrive at this conclusion, are, in some respects, arbitrary, although they are scarcely unnatural, but, from a more general consideration of this question, it appears probable that the value of y is never greater than $\frac{1}{2}$, and it may, in practice, be always estimated as exceeding $\frac{2}{3}$. If it should amount, in any case, to this last quantity, the use of springs would allow the load to be increased one-third, whence it may be seen of what importance a complete investigation of the most effectual mode of applying, and fashioning springs, would be to the machinist, and the engineer.]

"A final series of experiments executed in 1839, has had as its object, to ascertain the influence of the division of loads upon the injury. A wagon with four wheels, each 6.5 inches in breadth, and weighing 17,457 lbs., or about 650 lbs. on an inch of the breadth of the wheels —a cart with two wheels 6.5 inches broad, weighing 11,000 lbs., or 846 lbs., on an inch of the breadth—and eight smaller wagons with tires 2.4 inches broad, weighing each 3,960 lbs., or about 412 lbs. per inch of the breadth of the sustaining surface, and going in a train, one exactly behind the other, were drawn upon three tracks, taken in the same condition at the outset, and kept constantly wet and muddy.

After the transportation of 6,862 tons, it was evident that the four wagons drawn together, had caused much less injury than the other vehicles, and that the large wagon had done less harm than the cart, whose ruts had become so bad that it was almost impossible to draw it over the road.

"Hence, resulted the following conclusions. I. The division of loads upon many axletrees, or vehicles, is essentially favorable to the preservation of the roads. II. The wagons with tires 2.4 inches in breadth, going in trains, do less harm to the roads than large wagons and carts, carrying loads hitherto admitted. III. The load of 11,000 lbs. for a cart, and that of 17,457 lbs. for a four-wheeled waggon, (which amounts to about 10,406 lbs. on the hind-axletree) are so great as to occasion very remarkable injuries to the roads, and there is good reason to lay it down as a rule, that the load of carts, and that upon the hind-axletree of wagons, ought never to exceed much 8,800 lbs.

"Such were the most remarkable and important results of the experiments executed in 1839, by the order of the administration." Besides these experiments, of which a full account has here been given, to show the admirable manner in which they were conducted, another series was commenced in April, 1841, and continued until December, in the same year. As this series, however, was merely corroborative of those already described, and elicited no facts, or general laws, but what can be drawn from the others, it would be useless to translate more of M. Teste's report.

The experimental data which M. Morin has obtained, and, perhaps, the theoretical conclusions, which have been sketched in the foregoing pages, may do something to clear up, not only the question of the deterioration of roads, but the still more difficult problem of the laws of friction. So remarkable, and, apparently, irreconcilable, have been the variances between theory and experience, with regard to these laws, that mathematicians seem to have given up their investigation in despair, and Mr. Whewell has gone so far as to assert, that friction depends upon a distinct quality of matter, not yet discovered, and that it is vain to attempt to derive it from any of those common properties, with which we have hitherto had to do. Perhaps there is no good reason for so broad an assertion; perhaps more satisfactory results might have been obtained, by viewing the subject in a different light. It would, indeed, be idle to suppose, that the formulas, which have been given in this article, contain all that is necessary for a complete solution, or that they satisfy all the conditions of this intricate question. To do this would require a more subtle and careful analysis, than that here attempted; but the general method which has been employed, and the agreement of the equations, with the results of experiments, may not be unworthy of notice.

W.

Architecture.

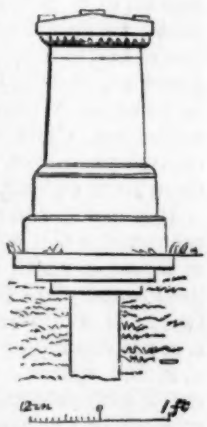
The Principles of Landscape-Gardening and of Landscape-Architecture applied to the laying out of Public Cemeteries and the Improvement of Churchyards; including Observations on the Working and General Management of Cemeteries and Burial-Grounds. By J. C. Loudon, F. L. S., H. S., &c.

II. THE LAYING OUT, BUILDING, AND PLANTING OF CEMETERIES.

(Continued from page 187.)

Sepulchral monuments, whether mausoleums (which is a term only applied to the most sumptuous description of tombs), square tombs, ledger-stones with inscriptions, sarcophagi, pedestals, vases, urns, columns, obelisks, pillars, crosses, &c., to have the appearance of security and permanence, ought to exhibit two features; they ought to be perfectly erect, or perpendicular, and they ought to rise from an architectural base. These features it is easy to exhibit when the monument is newly put up, but to continue them, even for a year, it is necessary to have a foundation of masonry under ground, as well as a basement above it; and, in order that this foundation may be permanently secure, it must be as deep as the adjoining grave, or graves. In the case of vaults and brick graves, this secure foundation is furnished by the structure itself; but in the case of common earth graves, a foundation requires to be built up, and the problem is how to effect this in a manner at once secure and economical. In most cemeteries and churchyards, and even in Père la Chaise, and Kensal Green, the greater part of the monuments have no other foundation than the moved soil, and only comparatively few are placed on the firm soil. The consequence of this is, that, in two or three years after the monuments are put up, they are found leaning to one side; or, if they are composed of several pieces, they are seen with joints rent, and conveying ideas the very reverse of permanence. Our remedy for the evil, is, two brick, or stone, piers at the head of each grave, carried up from the bottom, and from 9 in. to 2 ft. square, according to the depth. The two piers should be brought up at the same time, and tied together by building in pieces of iron hoop; and, when within a short distance of the surface, they should be joined by a semi-circular arch, or carried up to the surface, and connected by a lintel, which may be the visible base of the head-stone. Where a pedestal ornament of any kind, not more than 18 ins. on the side, was to be put up, one pillar 18 ins. square might suffice; or, when there was no danger of the ground being moved, even a 9-inch pier, as in fig. 5, would keep the pedestal from sinking. Where two graves

Fig. 5.



were built end to end, or side by side, three pillars would serve for both graves: and where four graves were to be made side by side, and end to end, three pillars would suffice; or, in effect, two pillars, as shown in fig. 6, the two half-pillars, at *a* and *b* not occupied, being charged by the builder to the cemetery, which would have a right to sell them to those who made adjoining interments. These pillars may be built in a few hours, by having beforehand portions of them prepared with brick and cement, in the manner familiar to every builder; or, in stone or slate countries, underground props of these materials might be formed; nor do we see any objection to cast-iron underground props. Where permanent endurance was the main object, we would not use cast-iron monuments; as it is next to impossible to prevent the rust from appearing through the paint, and scaling off so as to destroy, first the inscription, and next the body of the monument. In some of the London cemeteries, temporary labels of wood, having on them the number of the grave, or of the interment, and sometimes the name of the party interred, are used; and where economy is an object, and durability to the extent of a generation considered sufficient, we do not see any objection to the use of cast-iron tallies, such as fig. 7; their lower extremities being so fixed to a piece of wood, as to prevent them from being pulled out, while a circular disk, resting on two plain tiles, or bricks, will prevent them from sinking.

Fig. 6.

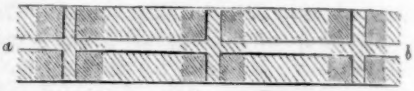
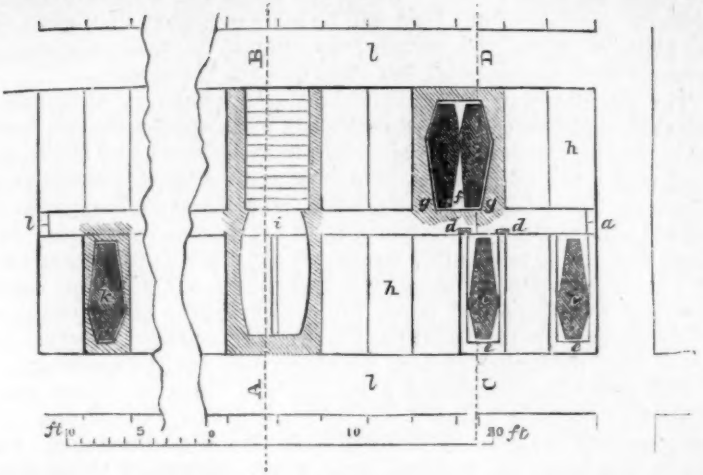


Fig. 7.

It is in order to supply room for head monuments that we have reserved a space of 2 feet in width between each double row of graves, as shown in the ground plan, fig. 8. In this figure, *a*, *b*, is the space between the two lines of graves, commencing and ending with a number-stone; *c*, *c*, are common graves with coffins, with piers for head-stones at *d*, *d*, and spaces for foot-stones, a foot in width, at *e*, *e*; *f*, is a brick grave with two coffins inserted, the head-stone to be placed between *g*, *g*, and *d*; *h*, *h*, are spaces left for common graves, brick graves, or, by occupying four divisions, for vaults; *i*, a vault for two coffins in width, occupying four divisions; *k*, a vault for one coffin in width, occupying one division; *l*, *l*, the green alleys between the double rows of grave beds, or panels.

When it is in contemplation to have a double line of brick graves, or to fill up a cemetery regularly, without allowing a choice to the purchasers, as in the cemeteries of the Jews, then a foundation wall 2 ft. in width, might be regularly carried up along the middle space, between the lines of graves, from one end of the line to the other.

Fig. 8.

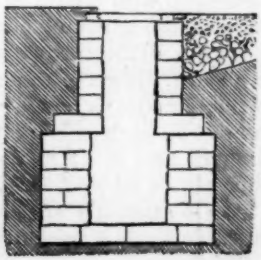


Cenotaphs, as every one knows, are monuments put up to the memory of persons who are interred somewhere else. They commonly consist of tablets with inscriptions, medallions, busts, basso-relievos, or other sculptural objects, and are very fit ornaments for affixing to walls under cover, or protected by architectural projections, such as those furnished by a chapel, a cemetery veranda, a boundary wall, or a structure erected on purpose, as is not unfrequent in the French and German cemeteries.

Walls, when used as the boundary of a cemetery, and built of brick, may be carried up hollow, which will be a considerable saving of material, and render all piers unnecessary, unless for effect, or, in the case of cemeteries laid out in imaginary squares, the piers which are to contain the stones having the letters and numbers.

The *main conveying-drains* of a cemetery, if built of brick, should be barrel-shaped, in the usual manner; but, if of stone, the bottom should be laid with flag-stone, and the same description of stone should be used for the covering. *Main collecting-drains* may be formed by semi-cylindrical tiles placed on flat tiles in the bottom, and sm all stones placed over them to within a foot, or less, of the surface of the ground. *Surface collecting-drains* may be 20 inches deep, formed like the last, with tiles at the bottom, and carried up to the surface with small gravel, finishing with coarse sand; and, when these drains are in the green alleys, grass may be sown over them. When at the sides of the gravel walks, or roads, they ought to communicate with surface gratings at regular distances; and immediately under each grating, there ought to be a pit 1 ft. square, and 2 feet

Fig. 9.



deep to retain the sand carried in by the water, (fig. 9,) this sand being taken out once a year. Where the roads and walks are laid with asphalte, gratings of this kind will be more necessary than when they are made of gravel, as a certain proportion of the water always sinks through the latter material, but none through the former.

The *furniture*, or tools, implements, and temporary structures, of large and complete cemeteries, consists of picks, spades, shovels, levers, rakes, scrapers, brooms; a rope and pulley, or block and tackle, to be used with a triangle; planks, ladders, grave-boards, dumcrafts, grave-platforms, grave-boxes, grave-moulds, wheelbarrows, buckets for raising soil, a frame for supporting canvas, or a tarpaulin over a grave while being dug during rain; and a temporary structure, consisting of a floor of boards, or wooden grating, with three sides, and a roof of canvas, rendered waterproof by paint, for the protection of the clergyman while reading the service at the grave; with another structure, of a larger size, for sheltering both the clergymen and the mourners.

The *grave-box* consists of a bottom and sides, the latter readily separating from the former; and its use is to hold the soil dug out of the grave, till the grave is ready to have the soil returned to it. From one to four boxes are required for a grave, according to its dimensions. Their use is two-fold: to preserve the soil from mixing with the grass, from which it is difficult afterwards to separate it so entirely as not to leave a quantity of it entangled among its leaves; and to return the earth in the most rapid manner to the grave. The box, before receiving the earth from the grave, is placed alongside, and raised up in a sloping position; the earth is thrown into it; and as soon as the coffin is lowered, the grave-diggers loosen and take out the side of the box next the grave, when the soil immediately begins to drop out, while, by raising the other side of the box, the whole is returned to the grave, and not a particle of earth is to be seen on the surface of the grass. This box was first used by Mr. Lamb, an undertaker in Leith, and is now in general use in the burial-grounds about Edinburgh. There ought to be a number of such boxes for every cemetery; and it would be an improvement to place them on low wheels, say those on the side which is to be next the grave of 6 inches in diameter, and those on the opposite side of double that height. This, while it would save the trouble of propping up the boxes, would also enable the grave-diggers to wheel them away, one after another, as fast as they were filled, and, when the grave was completed, to leave it quite free on every side, for the approach of mourners, who would in this case walk on the turf, instead of walking on loose earth, or planks. This result is sometimes obtained by throwing all the excavated soil into wheelbarrows, and removing these to a short distance, there to stand till the coffin is deposited. Either of these modes is much better than the common one of throwing up the soil on each side of the grave, and obliging the coffin-bearers to clamber over it. As the grave-boxes are readily taken to pieces, they can be stowed away, in sheds, or tool-houses, in little space.

A *clergyman's shelter* is unnecessary where a tarpaulin, or a movable shed, is used over the grave; but, where this is not the case,

it may be formed of five pieces, viz., a flooring of boards, or, to prevent slipping when the boards are wet, as well as to render the floor lighter, of wooden grating, raised one or two steps above the general surface, in order to give the reader of the service a more commanding position. To this floor three sides, each consisting of a frame of canvas, are readily fixed by means of studs in the lower rails of the sides, dropping into holes in the framework of the bottom; and they are as readily connected together by hooks dropping into eyes. The roof-piece, which ought to be raised a little in the middle to throw off the rain, can readily be dropped on four iron bolts, fixed in the upper ends of the styles of the sides. The whole may be painted black; and, when not in use, it should be taken to pieces, and kept in a dry, airy situation. A tent, or movable structure, to cover, not only the clergymen, but the mourners assembled, either during rainy weather, or hot sunshine, might be formed without difficulty, and at no great expense. The framework might be light iron rods; and the canvas might be so arranged as to be drawn up and let down, like the awnings to tulip beds, or the outside gauze shades to hot-houses.

Mechanics and Chemistry.

Iron-Founding.—From the Glasgow Pract. Mech. & Eng. Mag.

(Continued from Page 197.)

Section II.

Amongst the great variety of work denominated green-sand moulding, much and varied contrivance is displayed in the structure of the moulds. In particular, the management of cores is a matter of very considerable importance, and the malformation of them is a prolific source of failure in the production of sound castings.

Cores are especially useful for forming vacancies in castings. Their forms may be long, and proportionally small in diameter, or winding and otherwise intricate; and seeing that they are necessarily surrounded by the iron when cast, they ought to have, as much as may be, the qualities of firmness of substance, and openness of pores. Cores, as has already been stated in the first paper, are commonly composed of rock sand, and sea sand. The former, having a proportion of clay in its composition to which it owes its powerful cohesiveness, when dried, serves very well as a material for short cores that rest in the green sand at both ends, as open communication with it is thus afforded for the free escape of the air in the interstices of the cores. But when rock sand is used for cores of considerable length, (which, of course, are surrounded on all sides by the iron, except the small imbedded portions at the extremities, by which alone the air can escape,) it requires to be moderated by the admixture of free sand as a counteractant to the clay. The clay communicates the necessary cohesiveness to the material of the core: the sand, on the contrary, loose and open, renders it less binding, and more porous.

Free sand alone is also employed in the construction of confined cores, that they may afterwards be easily extracted, as the sand has naturally no power of cohesion. Wanting cohesiveness, it must be tempered to a proper consistency by the addition of clay and water, yest, or the refuse of the pease-meal, used for light, flat moulding purposes. In the use of the last material, it must be accurately proportioned to the sand with which it is mixed. The clay-water is, in ordinary cases, made use of as a cement, and the yest only in very particular circumstances. For large compact masses of core, the common green sand may be used, as illustrated in both examples, given in our last communication.

The longer cores are stiffened by iron wires, and small rods which are bent, if necessary, to the form of the cores. These rods are enveloped in the core in the progress of its formation, and are afterwards extracted from the casting. The cores of considerable length are pierced longitudinally by wires for the escape of the air; or, in cases in which this is impracticable on account of bends, or angles in the core, a piece of string is laid in the sand, alongside the stiffening wires, which is afterwards drawn out when the core is dry, leaving its perforation behind it.

With all these precautions for securing the strength of cores, and for the all-important purpose of letting off the air, blown holes do occur at times in castings, formed by the air thrown off the cores into the iron.

When the bearings of cores at the extremities are considered unfit for steadying them, they are further sustained by steeples stuck into the sand at several places in their length. These are simply nails with broad, flat heads, and several of them being set into the sand, and projecting above it just as much as the thickness of metal, the core is placed upon them, and sustained steadily in its place; the steeples are, of course, buried in the casting, and the points of them projecting outside, are chipped off in the course of dressing it. Chaplets* are also used to bear up cores having plane surfaces.

Fig. 1. Fig. 2. Fig. 3. Fig. 4.

An excellent example of the use of free-sand cores is found in the construction of bomb-shell mouldings. The form of a bomb-shell, it may be stated, is simply a hollow sphere of cast-iron, having one small round hole as a passage to the interior, termed the fuse-hole, as in the annexed sectional view, (fig. 1,) in which *a* is the fuse-hole. The pattern of the shell is a plain globe, (fig. 2,) of the same external diameter as itself, having a core print, *a*, upon it, answering to the fuse-hole, and of the same diameter. Fig. 3, represents the core, of

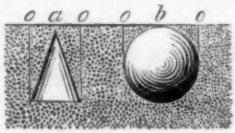
* In the last article, by a slight overlook, these objects are named steeples.

which the diameter is the same as that of the interior of the shell; it has a projection, *a*, to form the fuse-hole. The whole core is formed in a box which opens in two semispherical parts, to allow the core to be extracted. A piece of double-twisted wire is enveloped in the core, projecting at the neck with a loop at the outer end. By this wire the core is to be held down. Fig. 4, is a section of the moulding-box and the moulding, showing the core in its situation, and the applications for holding it there by means of the wire, which passes through the bottom of the moulding, and is locked on the under side. Two gates are also represented, by which the metal is poured.

It is evident, then, that when the casting is formed, the fuse-hole is the only exit for the core sand in the interior. The material of the core, ought, therefore, to be easily friable, as it can be broken down only by external blows. Accordingly, it is formed of free sand, so tempered with clay-water, or other binding principle, as to acquire just such a tenacity as will enable it to bear the action of the metal. The fuse-hole core is made of rock sand to enable it to bear the weight of the body of the core, and to withstand the strains to which it may be subjected. The surfaces of the core, and the exterior moulding, are washed with a mixture of blackening and water, to communicate smooth interior and exterior surfaces to the shell. A pricker is sent into the heart of the core through the neck, forming, by this means, a passage for the escape of the air confined throughout its substance.

Our next examples are intended to illustrate, generally, the manner of constructing patterns, in an exigency which frequently occurs, namely, when certain portions of a pattern enveloped in the sand, project horizontally beyond other parts which are above them. Were the pattern, in such circumstances, to be formed in one piece, it obviously could not be withdrawn from the sand without breaking up the moulding at the parts referred to. This idea may be explained by the annexed figures; *a*, *b*, fig. 5, being respectively a cone and a sphere. Were these objects buried in the sand, as shown in the fig., and then drawn out, the base of the cone would describe the space included in the vertical lines, *o*, *o*, and would, also, of course, remove the overlying sand. A similar result would ensue with the sphere. The lower part of the mould of the sphere would be left as it is, while the upper part between the lines, *o*, *o*, would be destroyed. The simple remedy for these cases would be to invert the position of *a*, as shown in fig. 6, and to mould the sphere, *b*, so as to have its largest horizontal diameter at the surface of the sand. While the under half could thus be moulded in the under box, the upper half would be rammed up in the upper box. As in these, so in all other instances, patterns, or parts of patterns, to be capable of being moulded in sand, must, in their general outline, taper from the surface of the sand downward. For this reason, such parts of the surface of a

Fig. 5.



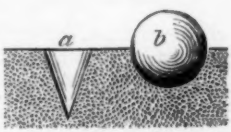


Fig. 6.

pattern as may be intended to be vertical, when it is being moulded, are never made truly so. A slight tapering inclination is given them, that they may leave the sand the more readily.

A variety of other peculiar circumstances, however, frequently occurs, which require special methods of management. For example, a common sheave requires a particular, and an elegant process, to execute the moulding of it. Fig. 7, is a diametrical section of one. The circumference, it will be observed, is grooved out semi-circularly at *a*, *a*, and a hole, *o*, is made through the centre. The object is now to mould the pattern in such a manner as that the portion of sand forming the groove, *a*, *a*, may be left in its place when the pattern is drawn out. The pattern, fig. 8, must be formed in two halves, separated by a plane, *a*, *a*, passing through the centre of the groove. These halves are prevented from shifting by pins, *n*, *n*, or this may also be effected by a button on the centre of the one, fitting a recess in the other, as in the figure. There are also prints at *o*, *o*, for supporting the core.

Fig. 7.

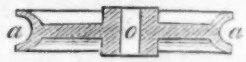


Fig. 8.

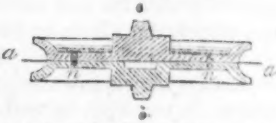
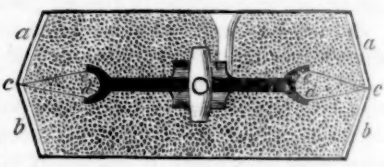


Fig. 9, represents, in section, the moulding of the pulley; *a*, *a*, and *b*, *b*, are the boxes. The pattern is first bedded in the lower box, and a parting, *c*, *d*, formed from the under rim to the edge of the box. The ring of sand, *c*, *d*, *e*, is, in the next place, rammed about the pattern, filling the groove, and its upper parting surface, *c*, *e*, is brought from the upper rim. Again, the upper box is placed on the other, and also filled.

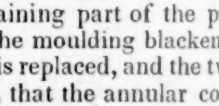
Fig. 9.



The ramming being now completed, and the gate-pin set, the box, *a*, *a*, is lifted off, carrying with it the impression of the upper side of the pattern. The upper half of the pattern being free, is lifted away, and the box, *a*, *a*, replaced. The whole is now inverted, and the box, *b*, *b*, is lifted off, thus permitting the remaining part of the pattern to be removed, which being done, and the moulding blackened and smoothed, and the core, *o*, set in, the box is replaced, and the two are finally reinverted. It will be observed, that the annular core, *c*, *d*, *e*, is never lifted from its situation during the process, and when the two boxes are linked together, it is wedged in on every side, and thus all possibility of shifting is removed.

Where there may not be facilities for turning the patterns of pulleys of large diameter, the grooves are cored out in the moulding. For this purpose, a core-print, running round the pattern, is provided in the making, as sketched in fig. 10, which is a section of the rim of a wheel supposed to be made with arms. The print is indicated by the dotted lines, and a core of the sectional

Fig. 10.



form, *a*, *b*, *c*, is constructed in a core-box for the purpose. As there are only two boxes for the moulding, the pattern is mostly imbedded in the under one, the parting being formed on a level with the core print at *a*. It is not necessary that the core be all one piece; it may, for convenience, be formed in several segments.

We shall now select a fluted stove-pipe, as an example of another variety of adaptation. Fig. 11, is a transverse sectional view of the pipe, which may be supposed to be about five inches diameter, six feet long, and three-sixteenths of an inch thick. It will be observed, that the core, or interior of the pipe, follows in form the exterior surface, the object being to make the pipe as light as possible, otherwise a round core might have served the purpose.

Fig. 11.

Fig. 12.

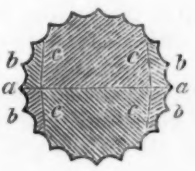
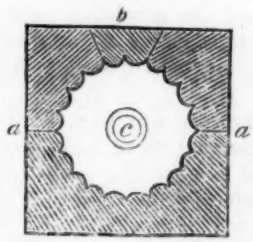


Fig. 13.

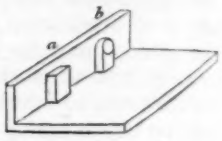


To determine, then, the method of casting this pipe:—It is to be noted, in the first place, as a general rule, that all cylindrical bodies of any considerable length, are moulded in two boxes, one half in each. Agreeably to this, the patterns are usually divided longitudinally in two halves. Referring to fig. 12, which is a cross section of the stove-pipe pattern, the line, *a*, *a*, represents the main division, which would suffice for a pattern having a plain exterior. For this column, however, deep as the flutes are, subdivisions are necessary to render the moulding of it practicable. For it is easily seen that the angles, *b*, *b*, *b*, *b*, immediately adjoining the parting, *a*, *a*, overhang the bottom of the hollows between *a* and *b*, and, therefore, if the patterns were drawn vertically out of the sand, they must break away the intervening portions of sand that occupy these hollows. Such parts of the pattern require to be removed laterally, and for this purpose, each half is made in three divisions, as represented at *c*, *c*, *c*, *c*, dovetailed to one another—allowing the smaller pieces to slide off the larger. Fig. 13, represents the core-box for the pipe. It is, like the pattern, parted in two at *a*, *a*. In the top of the upper half a loose piece, *b*, the length of the box, is provided, which being removed, the sand for the core may be introduced by the opening; *c*, is the core-bar, which runs the whole length for the purpose of stiffening the core.

The pattern having been moulded in the usual manner, one half in each box, so that the plane, *a*, *a*, fig. 12, coincides with the parting of the sand, the middle piece of each half is first drawn out, when the smaller pieces may next be removed laterally, to make way for the core.

On this principle of construction, in similar circumstances, patterns are generally made. Fitting strips, for example, when applied to the vertical face of a pattern, below the surface of the moulding, are attached to it by sliding dovetails. Core prints are very often placed in such circumstances. In fig. 14, which is the pattern of a flanched plate, *a* and *b*, are two core prints, which, instead of being dovetailed to the pattern, are carried quite down to the plate, which is moulded in an inverted position; these continuations clear the way for the prints themselves, which would otherwise break the moulding. After the cores are introduced, these temporary vacancies are filled up with the aid of smooth strips of wood, and the figure of the moulding restored. In general, core prints, on vertical faces of patterns, are carried up to the parting surface with the view of making their own passage, which is afterwards closed over the core.

Fig. 14.



Take, for our next example, a paneled octagon column, or post. It presents a more complicated structure than the stove-pipe, and to render it workable in the sand, the panels are, each by itself, made separable from the body of the pattern, being attached to it by screw-nails, which are driven off the inside. The pattern is divided into two principal halves. When it is moulded, the panels, of which there are four to each half, are fixed on. When the parts of the box are separated, exposing each a half interior of the pattern, the screws are returned and withdrawn, thus leaving the frame of the pattern at liberty from the panels. It is next lifted out, and these being disengaged from the sand by tapping, are likewise taken out in order. In this way a complete external moulding of the column is formed. The core, constructed upon a stout bar, is next inserted, and the box closed upon it.

Fig. 15.

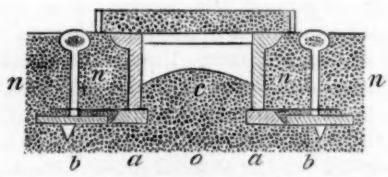
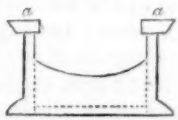


Fig. 16.



Of the use of plates in moulding, an example has already been given in our last paper in the account of the moulding of an engine sole-plate. A different application will now be described in relation to the moulding of a lathe-bed. Fig. 15, is an end view of the bed; *a*, *a*, are the upper sliding surfaces, overhanging the sides; these are connected and stiffened at several parts by deep flanches joining them. The surfaces, *a*, *a*, as they are the most important parts of the bed, are, according to the general rule, moulded undermost, the object being to secure a sound structure, at these parts, free from blown holes and impurities, which collect, more or less, towards the upper side of every casting. Fig. 16, is a section of the pattern and moulding.

The parts, *a*, *a*, are simply attached by loose pins to the rest of the pattern. The first step is to bed the pattern in an inverted position, thoroughly on the floor, which is levelled and smoothed all about it. Plates, *b*, *b*, extending the whole length of the pattern, are sent along both sides of it, an inch or so apart, to support the sand exterior to the pattern. A series of small rods, either of wood or iron, is placed on each plate. These rods overhang it on the side next the pattern, from which, however, they must be at some distance. In this way, the rods form a projecting platform, by which the sand that would overhang the plate is sustained. If of wood, the rods are dipped in clay-water, that they may adhere to the sand. The moulding is now made up with sand, flush with the pattern within and without. The parting surface is formed, and covered in by the upper box in the usual manner, which, being lifted off, and the pattern having been loosened, it is drawn out, leaving the loose pieces, *a*, *a*, imbedded in the three masses of sand, *n*, *n*, *o*. The masses, *n*, *n*, resting on the plates, are raised and moved aside by handles which are cast upon the plates, and project upwards. The pieces, *a*, *a*, being thus relieved, are edged out from below the sand, *o*, and removed. *n*, *n*, are replaced as before, guided by conical projections from the plates, and the moulding is covered in by the upper box.

Plates are also employed in the moulds of bevel-wheel patterns for lifting the bodies of sand sunk between the arms. Frequently, too, in miscellaneous cases, where considerable depths of sand occur in the upper part of the mould, slips of wood are planted vertically in the masses, reaching upwards between the ribs of the upper box, their object being to bind the whole body of sand the more firmly together.

(To be continued.)

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

Dynamometer for the Measuring of Steam, or Water, Power.

In your Journal for May, I find an article from the Edinburgh New Philosophical Journal, dated from Manchester, "On the method of registering the force actually transmitted through a Driving Belt; by Edward Lang, Esq., Professor of Civil Engineering, College, Manchester."

The method proposed is founded upon the extension, or stretch, of the belt, by the force communicated through it. That is, that the working side of the belt will be more extended than the slack side, and, consequently, the pulley on the machine will not revolve through so many inches, in a given time, as the drum that communicates the motion; or, in other words, suppose the working side of a belt may be extended one, two, or three, inches in an hundred, more than the slack side, it will, of course, lap round the driving drum, in that extended state; while the opposite side is received upon the driven pulley in the slack state, and will communicate so much less motion,

and as the difference between the motion communicated to the pulley, and that of the drum, will bear a certain proportion to the strain on the belt in each individual instance, the author says:—"We have only to contrive some method of registering this difference, in order to have a record of the total force transmitted by the belt." He then proceeds to a practical application of the principle, and proposes a plan for indicating the difference between the motion of the drums and the pulley, and also experiments with a particular belt, to ascertain what *force* a certain difference in these motions would indicate. He then says, "when the multiplier for one belt has been ascertained, that for any other belt may be approximately computed, if it be of the same material, by having regard to the relative weight of a foot of each," &c.

The reason of my calling your attention to this article, is, that the proposal of so imperfect and complicated a plan, shows the want of a good Dynamometer for this purpose, and that neither the writer of the article, a professor of civil engineering in the college of Manchester, nor the editor of the Philosophical Journal at Edinburgh, (though both might be supposed to be well informed on such matters,) were acquainted with a very simple and accurate instrument constructed for the purpose in this country, to which I am about to call your attention, as described in an article in the Monthly Chronicle, published in Boston, November, 1840.

"At the Mechanics' Fair in Boston, in September, 1839, an ingenious and valuable machine was exhibited, the purpose of which is to obtain an accurate measurement of the degree of power, exerted at any time, in the movement of machinery, while in regular operation. It is applicable alike to steam, or water, power, and is susceptible of being made of either large dimensions, for the measurement of the power of large water-wheels, or engines, or of smaller dimensions, applicable to the more exact measurement of the power exerted in the movement of light machinery. It is the invention of Samuel Batchelder, Esq., of Saco, the Agent of the York Cotton Factory. It is on a principle, which, we believe, is entirely novel, yet simple, and manifestly applicable to the accurate attainment of its object. In applying it to use, in any particular case, it is only necessary to place it in the line of communication, between the engine and machinery to be moved, by means of drum-belts, or gearing. When it is so placed, forming a line of connexion between the moving power, and the machinery to be moved, the degree of force exerted in overcoming the resistance to the motion of the machinery, at any given time, is accurately measured, by means of a steel-yard bar and weight. The position of the weight on the graduated bar, required for keeping this bar balanced in a horizontal position, indicates the measure, in pounds, of the power exerted at the time. There is connected with the machine an index, to show the number of revolutions of the drum connected with the water-wheel, or steam-engine, in a given time, by which, together with the weight, or resistance, to the motion, it will be readily shown how many pounds would be raised a foot high per

minute, or in any other space of time, by the degree of power then exerted. The form of the machine is illustrated by the following drawings

Fig. 1.

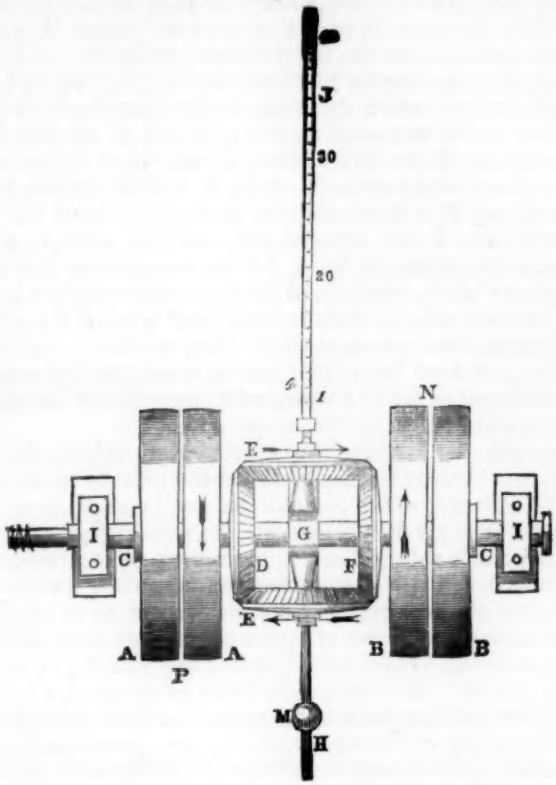
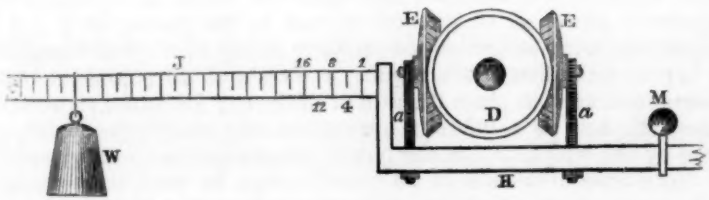


Fig. 2.



The cuts, figures 1 and 2, give a view of the dynamometer, in which AA, and BB, denote two pair of belt pullies, each pair consisting of a fast and loose pulley. The operation of the machine is to receive the motion, or power, from the drum, or prime mover, by a belt upon the pulley, A, and to transmit it to the machine, which is

the subject of experiment, by a belt on the pulley, B. The fast pulley, A, and the bevil wheel D are fast upon the shaft, CC, which revolves in the bearings, I I. The bevil wheel F, is connected with the pulley, B, by a tube, or hub, through which passes the shaft, CC, upon which this pulley and wheel are supported, the shaft revolving freely in the tube, or hub. In order to give motion to the pulley, B, a connexion must be formed between the bevil wheels, D and F; for this purpose they are geared together by the bevil wheels, EE, which run upon a cross shaft, through which the main shaft passes freely, at G. Now, it is evident, that if this cross shaft is not held in its place by some force, the motion of the bevil wheel, D, will only cause the shaft to move round and round upon the shaft, C, and the wheels, EE, rolling upon the wheel, F, without communicating to it, or to the pulley, B, any motion; but if the wheels, EE, and the shaft, G, are held in place, the motion of the pulley, A, will be communicated to the pulley, B, through the bevil wheels, and the force there applied to retain the shaft, G, and the wheels, EE, in place, will indicate the power transmitted through the dynamometer. This power is ascertained by means of a graduated beam, like that on a common balance, or steelyard, as represented by H J, attached to the shaft of the wheels, EE, as represented in fig. 2, by the straps, *a*, *a*.

The weight, M, fastened by a set screw, affords the means of balancing the lever horizontally, when the machine is at rest; and a weight, W, like that of the common balance, moved upon the graduated arm of the lever, will indicate the strain upon the belt. The number of pounds thus indicated, multiplied by the number of feet through which the belt moves per minute, will give the number of pounds raised one foot high per minute, according to the usual manner of estimating the power of steam engines, or other prime movers, allowing, as usual, 33,000 pounds raised one foot high per minute, to the horse power. A worm, on the end of the shaft, CC, is made to move an index, which shows the number of feet through which the belt, or the surface of the pulley, moves in a given time.

In graduating the arm of the balance, J, the division, marked 10, is at the same distance from the centre of the shaft, C, with the surface of the pullies, or equal to the radius of the pulley. The same additional distance is marked 20, and again the same 30. Now, if we suppose a power of 10 pounds applied to the pulley at P, it will balance the same weight on the opposite pulley at N; but it ought to be kept in mind that it will require a weight of 20 pounds at 10, to balance and keep in place the arm of the lever; for, as the pivot of the wheel, E, acts as a fulcrum, it must not only sustain the power exerted by the wheel, D, but the power communicated to the wheel, F, so that a counterbalance of 20 pounds must be used, to correspond with the numbers, 10, 20, 30, upon the graduated arm of the lever.

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

On the Strength of Cylindrical Steam Boilers.

Mr. Bakewell, of Cincinnati, replies to our article published in the July number of the Journal, (page 54) on the Strength of Cylindrical Boilers. Mr. B. misapprehends us; we do not, in our solution, assume any "parallelism in the action of the steam," as he supposes; but we admit that it acts, like other elastic fluids, perpendicularly to the inclosing surfaces—in this case the periphery of the cylinder. We have no objection to the new hypothesis which Mr. B. introduces, of a solid body below the line A, B, to which the semi-cylinder, A, B, D, is supposed to be attached, although we deem it unnecessary. The supposition, as he correctly states, does not alter the conditions of the problem. But then he errs greatly when he jumps to the conclusion, that "the operative force to produce rupture at B," would, by the received theory, be but one-half its value at D. Our equation—which is in accordance with the received theory—leads to no such incongruous result.

The general expression of the moment of the force, with reference to A, is,

$$\int \mathrm{F}x\frac{dx}{ds}ds+\int \mathrm{F}y\frac{dy}{ds}ds.$$

Now, if B be the point selected for the rupture, we have $x=\text{rad.}=\frac{\delta}{2}$, and must, accordingly, integrate from $x=o$, to $x=\frac{\delta}{2}$. By the operation we obtain,

$$\mathrm{F}\frac{\delta^2}{4}$$

for the moment of the force. The resistance of the metal is $\mathrm{P}t$; and the arm of the lever, by which it acts, is $\frac{\delta}{2}$, consequently, the moment of the resistance is here,

$$\mathrm{P}t\frac{\delta}{2};$$

which must be equal to the moment of the force; whence results,

$$\mathrm{F}=\frac{2\,\mathrm{P}t}{\delta},$$

as given by Mr. Latrobe. If Mr. Bakewell had read our former solution carefully, it would have spared him much trouble. E.

On a Self-acting Circular Dividing Engine; read before the Roy. Astron. Soc. Lond. June 9, 1843. By W. Simms, Esq.

The original graduation of a circle, notwithstanding the great improvements in the method invented by Mr. Troughton, is still attended

with very great difficulties, requiring not only the greatest care, on the part of the operator, but tending to injure his health by the labors required in it, and thus not admitting of frequent repetition. The necessary cost of an instrument produced by such an amount of severe labor, is also another very serious objection. The author had long been of opinion, that to copy the divisions of a circle which had been graduated with extraordinary care, upon work of smaller dimensions, would, in general, be more satisfactory than original graduation. The latter process consists of several successive steps, in either, or all, of which a certain amount of error may escape detection, which, in general, may go far to balance one another, although there will be parts in almost every work where errors appear arising from an accumulation of those minute quantities.

The author had long since determined, as soon as he could obtain sufficient leisure, to construct an engine sufficiently large for the graduation of all circles, excepting those of the largest class, and the object of this paper is to lay before the Society, a brief notice of the successful termination of the work.

The engine, in general arrangement and construction, is similar to that made by Mr. Edward Troughton, in the author's possession, though there are several additions and peculiarities which are pointed out by him. The circle, or engine-plate, is of gun-metal, 46 inches in diameter, and was cast in one entire piece by Messrs. Maudslay and Field, teeth being ratched upon its edge. The centre of the engine-plate is so arranged that it can be entered by the axis of the instrument to be divided, and the work, by this means, brought down to bear upon the surface of the engine-plate, which arrangement prevents the necessity of separating the part intended to receive the divisions from its axis, &c.—a process both troublesome and dangerous.

Upon the surface, and not far from the edge of the engine-plate, are two sets of divisions to spaces of five minutes, one set being in silver, and the other strongly cut upon the gun-metal face. There are also as many teeth upon the edge, as there are divisions upon the face of the engine-plate, namely, 4320, and, consequently, one revolution of the endless screw moves through a space of five minutes. The silver ring was divided according to Troughton's method, with some slight variations. In this operation it seemed to the author the safer course to divide the circle completely, and then to use a single cutter for ratching the edge; and he believes that the teeth upon the edge have been cut as truly as the original divisions themselves.

Another very important arrangement is, that the engine is self-acting, and requires no personal exertion, or superintendence, nothing being necessary but the winding up of the machine, or rather the raising of a weight, which, by its descent, communicates motion to the dividing engine. The machinery is so arranged, that it can be used, or dispensed with, at pleasure, there being some cases in which a superintending hand is desirable.

The author then proceeds with a description of the machinery, as represented in the drawings accompanying his paper, and draws

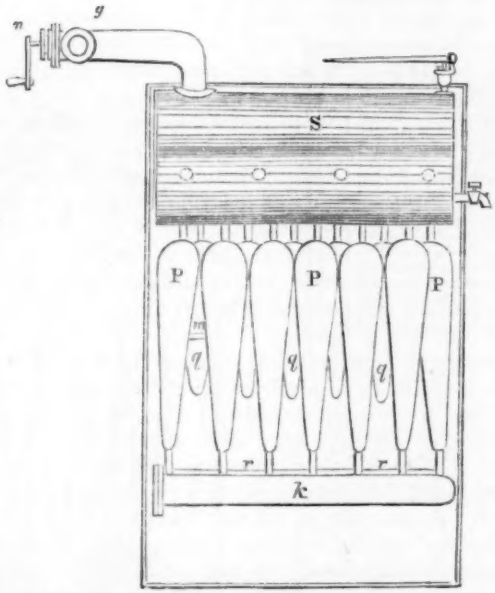
particular attention to the contrivance by which the engine can discharge itself from action when it has completed its work.

He concludes by observing, that as the machinery is simple, by no means expensive, can be made by an ordinary workman, is adapted to all the engines now in existence, which are moved by an endless screw, as it lessens the labor of the artist, and increases the accuracy of the graduated instrument, he trusts his communication will prove acceptable to all who are interested about such matters.

Lond. Edin. & Dub. Phil. Journ.

On the Steam Power of Mr. Henson's Flying Machine.

Fig. 1.



The difficulty of mechanical flying consists less in devising an apparatus capable of floating in, and being moved through the air in any given direction, than in freighting it with mechanical power sufficient to enable it to maintain its place through long distances against the constantly adverse influence of gravitation, and the frequently concurring opposition of the wind and weather. The means by which Mr. Henson hopes to overcome this difficulty, that is to say, the boiler by which he proposes to generate steam enough for any given length of flight, deserve, therefore, a little more consideration than they have as yet received at our hands. We, therefore, lay before our readers the accompanying engravings of the boiler, with the explanations furnished by Mr. Henson himself in his specification.—[Ed. *London Mech. Mag.*]

Fig. 1, represents a side elevation, and fig. 3, a front elevation of the boiler; figs. 2 and 4 are top and bottom sectional views. S, is the body, or principal part, of the boiler, consisting of three cylinders, the steam from which passes off through the pipe, *g*, which is provided with a valve. The smaller cylindrical vessels, *t*, *t*, are joined by the pipes, *u*, (four of which are indicated by dotted circles in fig. 1.) The larger conical vessels, P, P, P, connect the pipe, *k*, *k*, and the principal cylinders of the boiler, in the manner shown in the figures. The smaller vessels, *q*, *q*, are connected to the principal cylinders, as also to the vessels, P, P, as shown at *m*, figs. 1 and 3. The furnace is divided into two compartments by the vessels, P, P, P, as seen in fig. 2. *r*, *r*, are the furnace-bars, resting on the pipe, *k*, *k*, so that the vessels, P and *q*, are subjected to the full power of the fire; *f*, *f*, is the place of exit for the smoke.

Fig. 2.

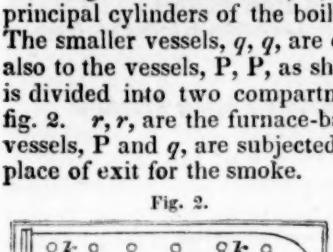


Fig. 3.

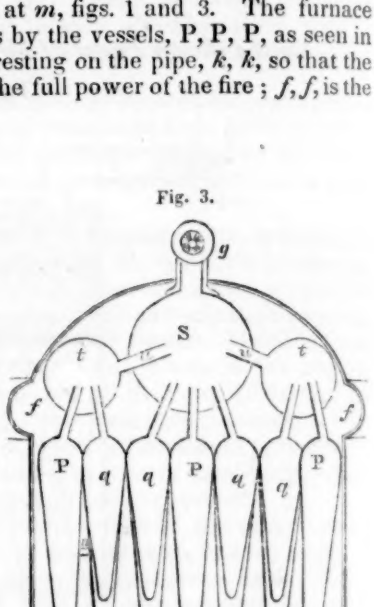
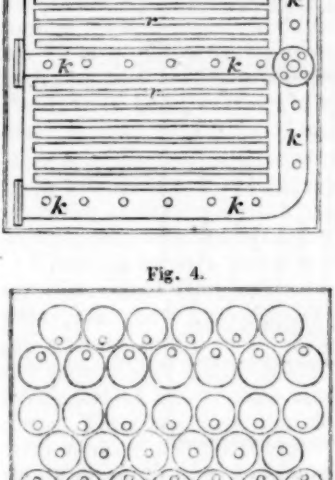


Fig. 4.



The vessels, S, *t*, P, and *q*, Mr. Henson proposes making of copper, and the joinings of brass, on account of the greater strength of copper when compared with iron, weight for weight, and also on account of its greater heat-conducting power.

The two induction and eduction valves of the engine, which are simply cocks varying little from the ordinary form, are to be worked by four eccentric wheels.

On the Electricity evolved by the Friction of Water and Steam against other bodies. By MICHAEL FARADAY, Esq.

The object of the experiments related in this paper, is to trace the source of the electricity which accompanies the issue of steam of high pressure, from the vessels in which it is contained. By means of a suitable apparatus, which the author describes and delineates, he found that electricity is never excited by the passage of pure steam, and is manifested only when water is at the same time present; and hence he concludes, that it is altogether the effect of the friction of globules of water against the sides of the opening, or against the substances opposed to its passage, as the water is rapidly moved onwards by the current of steam. Accordingly, it was found to be increased in quantity, by increasing the pressure, and impelling force of the steam. The immediate effect of this friction, was, in all cases, to render the steam, or water, positive, and the solids, of whatever nature they might be, negative. In certain circumstances, however, as when a wire is placed in the current of steam at some distance from the orifice whence it has issued, the solid exhibits the positive electricity already acquired by the steam, and of which it is then merely the recipient and the conductor. In like manner, the results may be greatly modified by the shape, the nature, and the temperature of the passages through which the steam is forced. Heat, by preventing the condensation of the steam into water, likewise prevents the evolution of electricity, which again speedily appears by cooling the passages, so as to restore the water which is necessary for the production of that effect. The phenomenon of the evolution of electricity in these circumstances, is dependent also on the quality of the fluid in motion, more especially in relation to its conducting power. Water will not excite electricity unless it be pure; the addition to it of any soluble salt or acid, even in minute quantity, is sufficient to destroy this property. The addition of oil of turpentine, on the other hand, occasions the development of electricity of an opposite kind to that which is excited by water; and this the author explains by the particles, or minute globules, of the water having each received a coating of oil, in the form of a thin film, so that the friction takes place only between that external film and the solids, along the surface of which the globules are carried. A similar, but a more permanent, effect is produced by the presence of olive oil, which is not, like oil of turpentine, subject to rapid dissipation. Similar results were obtained when a stream of compressed air was substituted for steam in these experiments. When moisture was present, the solid exhibited negative, and the stream of air positive electricity; but when the air was perfectly dry, no electricity of any kind was apparent. The author concludes with an account of some experiments in which dry powders of various kinds were placed in the current of air; the results differed according to the nature of the substances employed, and other circumstances.

Lond. Athenæum.

On the Action of Water on Lead; read before the Royal Society of Edinburgh. By Dr. CHRISTISON.

The author, after briefly stating the results of his experimental inquiries, published on this subject in 1829, proceeded to describe two instances which had recently come under his notice, illustrative of the solvent action of certain terrestrial waters on lead, and of the danger of using this metal for conducting water in pipes, unless with a due regard to the circumstances which promote, or prevent, its corroding property. In one instance, the water of a spring, conveyed in a lead-pipe from a distance of three quarters of a mile, was found to act so powerfully on the lead, that in a short time the cistern in which the water was collected became covered with loose carbonate of lead, and the metal could easily be detected in the state of oxide dissolved in the water. In this case, the action was found to depend on the spring being of extraordinary purity, its total saline ingredients being only a 22,000th part. In the other instance, water conveyed half a mile in a lead pipe, was impregnated exactly in the same way, and with the very same phenomena—but with the additional circumstance, that, in consequence of the impregnation not having been detected in time, as in the previous case, the disease, *Colica pictonum*, broke out in the house supplied with the water. In this case, the water was by no means pure, as it was found to contain no less than a 4,500th part of saline matter. But there was scarcely any other salt present except muriates, which the author had ascertained in his former researches not to prevent the action of water on lead, unless present in much larger quantity.

He next proceeded to explain in what manner the action of the water was put an end to in both these cases. In similar instances, the only remedy formerly thought of was substitution of iron-pipes. In the former of the two cases which fell under his notice, the water was left at rest in the pipe for four months, till a firm crust of mixed carbonate and sulphate of lead had crystalized on the lead; after which no farther action took place. In the latter instance, the same end was attained by keeping the pipe full of a solution of phosphate of soda, consisting of 27,000th of the salt.

The author appended an analysis of the compound formed by the action of distilled water on lead. Guyton-Morveau and others considered it a hydrated oxide; the author himself, in 1829, thought it a neutral carbonate; and, in 1834, Captain Yorke first considered it a hydrated oxide, and eventually concluded from his analyses, that it is an irregular mixture of hydrated oxide and carbonate of lead. The author finds that the product is a hydrated oxide, when the action goes on without the access of carbonic acid; but that, when the action proceeds in the usual way, under exposure to the atmosphere, the product is a crystalline body, of which the primitive form seems to be the regular octahedron, and which is composed of two equivalents of neutral carbonate, united with one equivalent of hydrated oxide ($2\,PbOCO^2 + PbG$ Aq.)

He then stated the following to be the general conclusions to be

drawn in a practical point of view, from his present and previous inquiries as to the use of lead for conveying water:

1. Lead-pipes ought not to be used for the purpose of conveying water, at least where the distance is considerable, without a careful chemical examination of the water to be transmitted.

2. The risk of a dangerous impregnation with lead is greatest in the instance of the purest waters.

3. Water, which tarnishes polished lead, when left at rest upon it in a glass vessel for a few hours, cannot be safely transmitted through lead-pipes without certain precautions.

4. Water, which contains less than about an 8000th of salts in solution, cannot be safely conducted in lead-pipes, without certain precautions.

5. Even this proportion will prove insufficient to prevent corrosion, unless a considerable part of the saline matter consist of carbonates and sulphates, especially the former.

6. So large a proportion as a 4000th, probably even a considerably larger proportion, will be insufficient, if the salts in solution be in a great measure muriates.

7. In all cases, even though the composition of the water seems to bring it within the conditions of safety, now stated, an attentive examination should be made of the water, after it has been running for a few days through the pipes. For it is not improbable that other circumstances, besides those hitherto ascertained, may modify the preventive influence of the neutral salts.

8. When the water is judged to be of a kind which is likely to attack lead-pipes, or when it actually flows through them impregnated with lead, a remedy may be found either in leaving the pipes full of the water, and at rest for three or four months, or by substituting for the water a weak solution of phosphate of soda, in the proportion of about a 25,000th part.

Edin. New Phil. Journ.

English Patents.

Specification of a Patent granted to William Cotton, Esq., of Leytonstone, *for an improved Weighing Machine. Patent dated June* 13, 1842; *Specification enrolled August* 10, 1842.

Mr. Cotton, who is Governor of the Bank of England, has invented this machine for the purpose of weighing sovereigns, and separating the light ones from those of standard weight. It is so delicate, that it detects, with precision, a variation of a twelve thousand two hundred and fiftieth part of the weight of a sovereign. The coins are placed in a tube, or hopper, from whence they are carried on to a small platform, which is suspended over a delicately poised beam, to the other end of which is appended the standard mint weight. On setting the machine at work, a sovereign is placed on the platform, and if it is full weight, a small tongue advances, and strikes it off into a till appointed to receive it; but, if it is light, the platform

sinks, and brings it within the reach of another tongue, at a lower level, which advances at right angles to the former tongue, and pushes the coin into another till. Other coins succeed in rapid rotation, so that the machine can weigh, and sort 10,000 sovereigns in six hours, while an experienced teller, can, at the utmost, only weigh between 3,000 or 4,000 coins, by hand-scales, in the same time, and even then, the optic nerve, by incessant straining, becomes fatigued, and errors occur.

Lond. Mech. Mag.

Specification of a Patent granted to SAMUEL DOTCHIN, of Hoxton, *for improvements in paving, or covering and constructing roads, ways, and other surfaces. Sealed 8th October,* 1842.

These improvements consist in paving roads, &c., with blocks of wood, or other suitable material, of the peculiar form represented in fig. 1, which is a side view, and fig. 2, a plan of the block; the latter fig. being encompassed by a circle, to shew that it may be cut out of a circular block, or piece of timber. The improved block consists of six sides, and an upper and lower surface; the sides are all equal, but, instead of being formed perpendicular to the upper and lower surfaces, they incline alternately in opposite directions. The advantages to be derived from this form, are, that each block will be supported by three of the adjoining blocks, and will also support three, as shewn at fig. 3, which is a plan of part of a pavement; the spaces between the upper parts of the blocks are filled with asphalte, sand, &c.

Fig. 1.

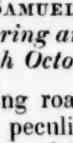
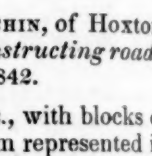


Fig. 2.

Fig. 3.



The patentee does not claim the use of blocks of wood, or other material, with six sides, generally, but only when the sides are caused to incline in opposite directions, as shewn in the drawing, in order that each block may support, and be supported, by the surrounding blocks. He claims, also, combining a series of blocks, of the figure above described, for paving, or covering, and making roads, ways, or other surfaces.—[Enrolled in the Enrolment Office, April, 1843.]

Ibid.

Abstract of a Patent granted to CHARLES KEENE, of New Bond street, *for improvements in the manufacture of hose, socks, drawers, gloves, mitts, caps, comforters, and cuffs.* Patent dated December 15, 1842; Specification enrolled June 15, 1843.

Mr. Keene premises, that he has found that when fabrics into which threads of Indian rubber have been introduced, are cut up in lines parallel to these threads, the cloth is not apt to fray, or fringe, out. Applying this fact, he forms elastic bands for the wrists of gloves, by introducing threads of Indian rubber as weft, or warp. In either case he forms a band of sufficient width for the required wrist; be-

tween the threads of Indian rubber, he introduces one or two picks of wool, or cotton, &c., according to the fabric, but preferring wool. Immediately in contact with this band, there is woven a sufficiency of stuff, from which may be cut the glove, leaving the band at the top to become the wrist, so that the web may consist of as many breadths, or lengths, as may be convenient, taking care only, to have a band, into which has been woven the India rubber, to become the elastic wrist. The caoutchouc may be rendered elastic in the usual manner, either before it is woven, or afterward.

Another part of the invention has reference to the manner of cutting out, or forming, what he calls *overalls* for gloves, stockings, mitts, caps, drawers, &c., which are used to keep the gloves, &c., underneath, close to the body for warmth. They are to be cut from a web into which threads of India rubber have been introduced, either as warp, or weft, or from a fabric formed similar to that made by the warp lace machines, either diagonally, or longitudinally. The overalls, &c. &c., are to be cut in such a manner, that the threads of Indian rubber shall take a diagonal direction over the hand, when they will be found readily to yield to the form of the hand, &c.

The claims are: 1. To the application of elastic bands, made in warp machines, as above described.

2. The making of the fabric in manner above described, so that when the gloves, &c., are cut out, there shall be an elastic band for the wrist.

3. The mode above described, of making overall gloves, mitts, &c., so that the threads of Indian rubber shall always lie in a diagonal direction across the hand, &c., whether the fabric be made by the common warp, or by warp lace machines. Ibid.

Abstract of a Patent granted to William Henry Fox Talbot, Esq., of Laycock Abbey, *for improvements in coating, or covering, metals with other metals.* Patent dated November 25, 1842. Specification enrolled May 25, 1843.

The specification of Mr. Talbot's present patent discloses no new principle in the art of metallic precipitation; but it supplies some very useful improvements in its manipulative details.

1. To prepare metal articles for gilding, Mr. Talbot dips them in a weak solution of silver in hyposulphite of soda.

2. To prepare an article for either gilding, or silvering, he first cleans it well, then connects it to one of the wires of a voltaic battery, next plunges both poles into a vessel filled with some acid solution, which, decomposing the water, the hydrogen is given off by the article intended to be gilt, or silvered. After a little time the article is detached from the battery, and thrown into a solution of gold or silver, where it speedily acquires the required coating.

3. To gild metallic articles, he makes use of a mixed solution of gold, and any one of the baser metals, with the exception of mercury, which would separate the gold.

4. He also uses for gilding, a solution of chloride of gold, mixed with a solution of boracic acid, the latter having the effect of greatly improving the color.

5. To remove the dark tint which metallic articles sometimes acquire when dipped in a solution of gold, they are immersed in a very weak solution of nitrate of mercury. Any mercury which may adhere, is afterwards removed by an acid, assisted by voltaic action.

And, 6. When, in silvering an article, the solution of silver ceases to impart any addition to the coating, (in consequence of the coating and the solution becoming of identical properties,) Mr. Talbot dips it into a different solution of silver, or into a solution of some other metal, after which he replaces it in the first solution, when it is found to act with the same energy as at first. The same method of alternate dipping is also applicable to solutions of gold. Ibid.

METEOROLOGICAL OBSERVATIONS FOR FEBRUARY, 1843.

Moon	Days.	Therm. Sun Rise.	Therm. 2 P. M.	Barometr. Sun Rise.	Barometr. 2 P. M.	Wind. Direction.	Wind. Force.	Water Fallen in rain	State of the Weather, and Remarks.	
	1	33°	26°	29.36	29.36	NW.	Moderate		Cloudy.	Cloudy.
	2	18	26	29.70	29.86	W.	Blustering		Clear.	Clear.
	3	20	33	30.10	30.10	S.	Moderate		Clear.	Clear.
	4	24	38	30.10	30.10	S.	do		Hazy.	Hazy.
	5	34	32	29.70	29.36	NE.	do		Cloudy.	Cloudy.
	6	21	23	29.33	29.50	W.	Blustering		Cloudy.	Par. cloudy.
☾	7	12	22	29.70	29.75	W.	do		Par. Cloudy.	Clear.
	8	11	20	30.10	30.15	W.	Moderate		Clear.	Cloudy.
	9	12	26	30.27	30.27	W.	do		Clear.	Lightly cloudy.
	10	19	32	30.35	30.30	E.	do	.66	Cloudy.	Lightly rain.
	11	41	40	29.60	29.66	W.	Blustering		Cloudy.	Clear.
	12	33	38	29.83	29.83	W.	do		Par. Cloudy.	Clear.
	13	24	24	30.05	30.05	NE.	Moderate		Flying clouds.	Cloudy.
☉	14	23	23	29.90	29.83	NE.	Blustering		Cloudy.	Cloudy.
	15	29	24	29.45	29.45	W.	do	.65	Sleet,	Cloudy.
	16	12	29	29.90	29.95	W.	Moderate		Clear.	Cloudy.
	17	13	25	30.10	30.00	W.	do		Clear.	Cloudy.
	18	11	25	30.24	30.00	SE.	do		Cloudy.	Hazy.
	19	19	33	30.05	29.90	NE.	do		Cloudy.	Clear.
	20	33	37	29.60	29.90	W.	do		Par. Cloudy.	Clear.
☽	21	22	30	29.50	29.50	NW.	Brisk		Cloudy.	Par. cloudy.
	22	30	35	29.55	29.37	SE.	Moderate	.16	Cloudy.	Snow.
	23	14	28	29.80	29.80	W.	Brisk		Clear.	Clear.
	24	24	36	29.80	29.75	E SE.	Calm		Cloudy.	Lightly cloudy.
	25	22	38	29.70	29.70	W.	do		Clear.	Lightly cloudy.
	26	30	47	29.80	29.50	W.	do		Clear.	Lightly cloudy.
	27	31	43	29.50	29.50	W.	do		Clear.	Lightly cloudy.
⊗	28	28	39	30.00	30.00	E.	do	.07	Clear.	Lt. cloud, snow.
		22.96	31.14	29.82	29.80			1.48		

Thermometer.		Barometer.	
Maximum 47 on 26th.	Mean, 27.05	Max. 30.35 on 10th.	Mean 29.8
Minimum 11 on 8th & 18th.		Min. 29.33 on 6th.	